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UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Fisheries and Federal Aid

FISHERY AND AQUATIC MANAGEMENT PROGRAM
in
YELLOWSTONE NATIONAL PARK

Technical Report for Calendar Year 1991

June 1992

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ANNUAL PROJECT TECHNICAL REPORT FOR 1991

Fishery and Aquatic Management Program

Yellowstone National Park

Ronald D. Jones, Project Leader

June 1992

Authors (alphabetical):

Roger Andrascik, Resource Management Coordinator, Lake Ranger District, National Park Service: Lake Area-Bridge Bay spawning survey.

Daniel G. Carty, Fishery Biologist, FWS: Parkwide angling, Yellowstone Lake, Yellowstone River, Nonangling use of the aquatic resource, Lake Area-Bridge Bay spawning survey, Grant Village spawning survey, Lewis River Channel.

Ronald D. Jones, Project Leader, FWS: Introduction.

Lynn R. Kaeding, Assistant Project Leader, FWS: Firehole River, Other project activities.

Barbara M. Kelly, Research Assistant, Montana State University Cooperative Fishery Research Unit: Yellowstone River angler wading study.

Daniel L. Mahony, Fishery Biologist, FWS: Fluvial Arctic grayling study, Postfire investigations, Lamar River, Soda Butte Creek.

Tom Olliff, Resource Management Coordinator, Snake River Ranger District, National Park Service: Grant Village spawning survey, Lewis River Channel.

Cover photo: The lower Firehole River in Firehole Canyon, between Firehole Falls and Firehole Cascades. Image from a glass-plate negative made by the U.S. Army Corps of Engineers in 1913. The Corps of Engineers was Yellowstone National Park to supervise the construction and maintenance of roads and bridges.

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INTRODUCTION

Yellowstone National Park is one of the few largely pristine ecosystems in the contiguous United States. Encompassing 890,000 hectares (3,500 mi^2) in the northwest corner of Wyoming and adjacent areas of Montana and Idaho, the park is bordered on the north and east by mountains that rise to 3,400 m (11,000 ft). Yellowstone is characterized by several broad, forested, volcanic plateaus that contain the world's largest volcanic caldera and thousands of geysers and other geothermal resources.

In 1872, the United States Congress established Yellowstone, the Nation's first national park, ". . . for the benefit and enjoyment of the people and for the preservation, from injury and spoliation, of all timber, mineral deposits, natural curiosities and wonders . . . and their retention in their natural condition." Today, the perpetuation of natural ecosystem processes is a primary goal of management in Yellowstone National Park.

Slightly over 5 percent of the surface area of the park is water. More than 150 lakes constitute an area of about 43,000 hectares (108,000 acres), of which Yellowstone, Shoshone, Lewis, and Heart lakes make up 94 percent. More than 220 named and hundreds of unnamed streams constitute over 4,300 km (2,650 mi) or about 2,000 hectares (5,000 acres) of flowing water.

Yellowstone National Park provides exceptional recreational opportunities for anglers and other visitors. Federal legislation and National Park Service policies have evolved to closely regulate fishing in the park. Although nearly 3 million people visit the park each year and an estimated 403,000 angler days were spent fishing park waters in 1991, angling regulations formulated by the U.S. Fish and Wildlife Service (USFWS) and National Park Service have resulted in self-sustaining fish populations with characteristics resembling those from unfished waters. The USFWS and its predecessors have assisted in the management of the aquatic resources of the park since 1889.

In Yellowstone National Park, quality angling is defined and successfully promoted as the opportunity to fish for wild trout in a pristine environment. Although limited harvest of fish by anglers is allowed, fish are primarily reserved for grizzly bears, river otters, eagles, ospreys, pelicans, and other animals for which fish are important food.

The goal of the aquatic management program of Yellowstone National Park is:

> To pursue an aquatic management policy that allows ecological processes to function as if uninfluenced by

modern man, while providing for visitor use and education

Specific objectives are to:

- Describe the qualitative and quantitative characteristics of the fish populations, associated biota, and other aquatic resources of Yellowstone National Park

- Determine how visitor use and other factors affect the dynamics and trends of fish populations, associated biota, and other aquatic resources

- Recommend measures to minimize the effects of human activities on the fish populations and other aquatic resources

- Maintain or restore, in numbers sufficient to assure their long-term persistence, aquatic ecosystems and their fish-species assemblages representative of those present upon the arrival of European man in Yellowstone National Park

The U.S. Fish and Wildlife Service evaluates the response of the fishery and aquatic ecosystem of Yellowstone National Park to the fishery and aquatic management program to assure program adherence to National Park Service policies. This report describes the results of investigations conducted in 1991.

PARKWIDE ANGLING

Nearly 3 million people--the most on record--visited Yellowstone National Park in 1991. The National Park Service issued approximately 187,200 free fishing permits this year; however, exit-gate surveys (interviews with visitors leaving the park) revealed that 16% of permit holders did not fish and resulted in an estimate of 161,100 anglers for 1991 (Table 1). The following sport-fishery statistics were estimated using data from exit-gate surveys and the Volunteer Angler Report system (a voluntary postal creel survey).

In 1991, parkwide angler use (number of fishing trips) and effort (hours spent fishing) were 403,000 angler days and 1,059,300 h. Although angler use in 1991 decreased 5% compared to 1990, angler effort increased 2% because the average length of the angler day in 1991 was greater than in 1990 (Table 2). Anglers landed 1,039,700 fish this year and creeled 66,600 of these (i.e., approximately 94% of all fish landed were released). The average angler fished 2.2 d, 1.3 waters/d, and 2.6 h/d. Average landing and creel rates were 0.98 and 0.06 fish/h (Table 2).

Species composition of fish landed was 70% cutthroat trout *Oncorhynchus clarki*, 10% rainbow trout *Oncorhynchus mykiss*, 8% brook trout *Salvelinus fontinalis*, and 7% brown trout *Salmo trutta*. Mountain whitefish *Prosopium williamsoni*, lake trout *Salvelinus namaycush*, Arctic grayling *Thymallus arcticus*, and unidentified fishes made up the remaining 5% of angler-landed fish.

Mean length of 53,437 angler-landed fish was 339 mm (13 in); about 67% of these fish were ≥305 mm (12 in) long, and nearly 54% were ≥356 mm (14 in) long. Average length of lake trout was largest (451 mm or 18 in), followed by cutthroat trout (372 mm or 15 in), unidentified fishes (347 mm or 14 in), mountain whitefish (296 mm or 12 in), brown trout (292 mm or 12 in), rainbow trout (274 mm or 11 in), Arctic grayling (240 mm or 9 in), and brook trout (182 mm or 7 in).

Approximately 81% of park anglers were satisfied with their overall fishing experience; 72 and 74% were also satisfied with sizes and numbers of fish landed. Anglers satisfied with their fishing experience landed about 3 fish/d (mean length, 345 mm or 14 in), and anglers unsatisfied with their fishing experience landed about 1 fish/d (mean length, 279 mm or 11 in). Mean angling-expertise level was 1.9 (experienced).

Sport-fishery statistics for 19 lakes and streams that collectively constituted over 94% of parkwide angler use in 1991 are listed in Table 3.

TABLE 1.-Estimates of park visitors, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1973 to 1991.

Year	Total park visitors	Park fishing permits issued	Total parkwide anglers	Total parkwide angler days	95% confidence limits
1973	2,061,537	169,103	121,888	230,100	225,500 - 234,700
1974	1,928,915	164,600	116,518	220,000	215,500 - 224,300
1975	2,239,483	191,550	136,332	257,300	248,400 - 266,300
1976	2,519,224	213,200	151,730	284,200	278,500 - 298,900
1977	2,481,933	217,000	154,581	311,300	304,000 - 318,500
1978	2,618,380	218,000	155,700	333,800	326,200 - 341,300
1979	1,892,908	195,100	139,100	291,300	274,500 - 308,200
1980	2,000,273	184,200	130,800	311,300	287,000 - 334,600
1981	2,521,831	172,300	160,000	383,400	363,400 - 403,300
1982	2,368,897	205,000	152,000	332,500	314,700 - 350,300
1983	2,347,242	166,800	120,500	275,900	261,800 - 289,900
1984	2,222,027	176,800	135,000	329,200	305,400 - 341,000
1985	2,226,159	166,700	123,800	279,000	260,800 - 297,200
1986	2,363,75	163,300	124,900	294,800	269,300 - 320,400
1987	2,573,194	183,900	151,500	370,900	349,062 - 392,804
1988	2,182,113	165,700	134,600	293,800	272,716 - 314,917
1989	2,644,442	159,200	124,360	320,900	301,100 - 340,700
1990	2,857,096	171,724	150,389	422,097	386,708 - 457,486
1991	2,957,856	187,247	161,126	403,079	372,468 - 433,774

TABLE 2.-Estimates of angler use, effort, success, and harvest for Yellowstone National Park, 1973-1991.

Year	Angler days	Mean length of angler day (h)	Total hours fished (days x h)	Landing rate	Total fish landed	Creel rate	Total fish creeled	% of anglers satisfied with Overall experience	Numbers caught	Sizes caught	Average length of fish landed (in)	Mean expertise[a]
1973	230,100	2.45	564,400	0.86	485,400	0.16	90,300	--	--	--	--	--
1974	220,000	2.42	531,300	0.86	456,900	0.19	101,000	--	--	--	--	--
1975	257,300	2.31	594,400	1.09	647,900	0.23	136,700	77	74	75	13.3	--
1976	284,200	2.36	670,700	1.02	684,100	0.20	134,100	74	69	69	13.2	1.90
1977	311,300	2.33	725,300	0.98	710,800	0.20	145,100	75	68	70	13.4	1.83
1978	333,800	2.23	744,400	0.99	736,900	0.17	126,500	73	66	68	13.4	1.86
1979[b]	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	13.6	1.88
1980	311,300	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	13.4	1.87
1981	383,400	2.41	923,000	0.93	844,700	0.12	110,800	73	65	66	13.4	1.88
1982	332,500	2.34	777,600	0.95	740,200	0.14	107,500	74	67	68	13.5	1.88
1983	275,900	2.36	652,100	0.95	622,400	0.11	71,600	76	69	68	13.6	1.89
1984	329,200	2.40	790,100	0.93	732,700	0.12	92,100	76	68	69	13.5	1.91
1985	279,000	2.47	688,500	0.92	629,700	0.10	69,800	76	68	71	13.3	1.90
1986	294,800	2.49	734,700	1.01	740,900	0.10	73,400	79	72	72	13.3	1.93
1987	370,900	2.47	917,800	0.94	865,900	0.07	61,600	73	64	66	12.3	1.93
1988	293,000	2.56	753,400	1.05	788,100	0.09	65,300	78	69	70	12.8	1.90
1989	320,900	2.50	801,300	0.92	735,800	0.07	55,400	77	68	71	13.2	1.91
1990	422,100	2.47	1,042,900	0.97	1,009,900	0.06	61,700	80	71	73	13.3	1.88
1991	403,100	2.62	1,059,300	0.98	1,039,700	0.06	66,600	81	72	74	13.4	1.90

[a] Based on: 1.0 = inexperienced; 2.0 = experienced; 3.0 = expert.
[b] Revised from that reported in Jones et al. (1980).

TABLE 3.-Fishery statistics for Yellowstone National Park waters with 40 or more angler days and which collectively comprise over 94% of the estimated parkwide angler use in 1991.

	% of total parkwide angler days	Total reported angler days (VAR)	Anglers	Mean length of angler day (h)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creeled	Mean length fish landed (inches)	Mean length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with: Overall experience	Numbers caught	Sizes caught
Parkwide fishery	100	11,387	161,126	2.63	403,079	1,059,291	0.98	0.06	1,039,730	66,643	13.35	12.07	72	1.90	81	72	74
Yellowstone Lake	37.95	4,321	52,987	2.79	152,943	426,324	1.05	0.09	446,334	37,406	15.43	12.42	78	1.77	85	77	82
Yellowstone River	16.45	1,873	25,268	2.69	66,284	178,313	0.90	0.01	160,324	2,353	15.27	13.31	69	1.99	84	76	85
Firehole River	6.81	775	12,230	2.55	27,415	69,973	0.80	0.02	55,838	1,479	9.73	8.53	68	1.97	76	63	54
Madison River	6.67	760	10,350	2.48	26,884	66,723	0.51	0.02	34,288	1,096	12.96	12.50	47	1.96	62	49	57
Slough Creek	5.03	573	8,899	3.04	20,264	61,645	1.10	0.01	67,760	727	13.32	-	84	2.00	89	79	86
Gibbon River	4.53	516	9,327	1.84	18,246	33,639	1.02	0.09	34,385	3,134	7.72	8.30	65	1.94	67	58	49
Lewis Lake	2.97	338	4,330	3.05	11,945	36,435	0.49	0.17	17,867	6,153	14.53	15.69	53	1.89	74	61	74
Gardner River	2.13	243	3,878	2.35	8,582	20,177	1.00	0.09	20,079	1,903	8.47	9.35	77	1.82	85	75	59
Lamar River	2.02	230	4,354	2.37	8,122	19,266	1.14	0.03	21,983	614	11.66	11.30	77	2.08	81	67	74
Shoshone Lake	1.94	221	2,118	3.40	7,803	26,541	0.71	0.12	18,875	3,158	17.25	17.59	54	1.95	68	62	88
Soda Butte Creek	1.77	201	3,498	2.14	7,095	15,215	1.53	0.07	23,287	1,020	10.25	12.58	79	1.97	83	73	72
Gallatin River	1.52	173	2,593	2.64	6,104	16,104	0.92	0.03	14,768	458	11.47	12.43	82	2.08	79	66	78
Indian Creek	.83	94	1,332	1.81	3,307	5,998	1.54	0.35	9,246	2,123	6.27	7.59	56	1.91	73	64	39

TABLE 3.-Continued.

	% of total parkwide angler days	Total reported angler days (VAR)	Anglers	Mean length of angler day (h)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creeled	Mean length fish landed (inches)	Mean length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
															Overall experience	Numbers caught	Sizes caught
Grebe Lake	.79	90	1,761	2.64	3,166	8,341	1.94	0.06	16,153	461	9.88	14.47	92	1.93	89	80	82
Lewis River	.68	77	1,594	2.00	2,705	5,418	0.72	0.04	3,888	241	9.73	15.89	44	1.92	67	63	56
Obsidian Creek	.62	71	1,451	1.77	2,493	4,408	1.58	0.23	6,975	1,030	6.53	8.22	78	1.95	82	85	56
Nez Perce Creek	.55	63	1,332	1.87	2,210	4,133	0.97	0.04	4,005	148	8.51	10.60	64	1.88	77	75	45
Bechler River	.42	48	857	3.22	1,679	5,410	0.63	0.01	3,389	64	10.66	–	79	2.09	61	67	52
Tower Creek	.38	43	714	1.94	1,502	2,911	1.38	0.37	4,004	1,073	8.42	8.28	100	1.93	100	97	90

YELLOWSTONE LAKE

The Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* population of Yellowstone Lake has been altered by human activities during the past 100 years (Gresswell and Varley 1988). A commercial fishery supplied cutthroat trout to hotels and restaurants in Yellowstone National Park in the late 1800s and early 1900s, and millions of cutthroat trout eggs were shipped out of the park as part of large-scale hatchery operations between the early 1900s and 1953. Additionally, sport anglers have annually harvested thousands of cutthroat trout from the lake, and three nonnative fishes have been introduced.

Angling regulations on Yellowstone Lake date back to the late 1800s. Although creel limits were reduced between 1900 and 1968, the abundance of trout stocks in the lake declined (Gresswell 1980). In 1970, a daily limit of three fish ≥356 mm long was implemented, and in 1973 the daily limit was reduced to two fish. Despite these changes in regulations, the relative abundance of trout ≥356 mm long in the population failed to increase (Gresswell 1980). Consequently, a 330-mm maximum-size limit was instituted on Yellowstone Lake in 1975 and on all tributaries of Yellowstone Lake in 1978.

Jones et al. (1977-1987) analyzed trends in the Yellowstone Lake fishery from 1975 through 1986 and, along with Gresswell and Varley (1988), concluded that the 330-mm maximum-size limit had successfully reduced angler harvest and increased the relative abundance of large (≥356 mm), old (≥5 years) cutthroat trout. Since 1986, efforts to monitor trends in the Yellowstone Lake fishery have continued annually (Jones et al. 1988-1990). The objectives of this report were to present results from investigations conducted in 1991 and evaluate long-term trends in the fishery through 1991.

Study Areas

Yellowstone Lake

Yellowstone Lake (Figure 1) is located in east-central Yellowstone National Park and lies 2,357 m above mean sea level. It has a drainage basin of 2,616 km^2, a surface area of 354 km^2, and a mean depth of 40 m (Benson 1961). Ice covers the lake from mid-December through May or early June, and summer surface temperatures rarely exceed 18°C. Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae* are the endemic fishes of Yellowstone Lake. Introduced fishes include longnose sucker *Catostomus catostomus*, redside shiner *Richardsonius balteatus*, and lake chub *Couesius plumbeus*.

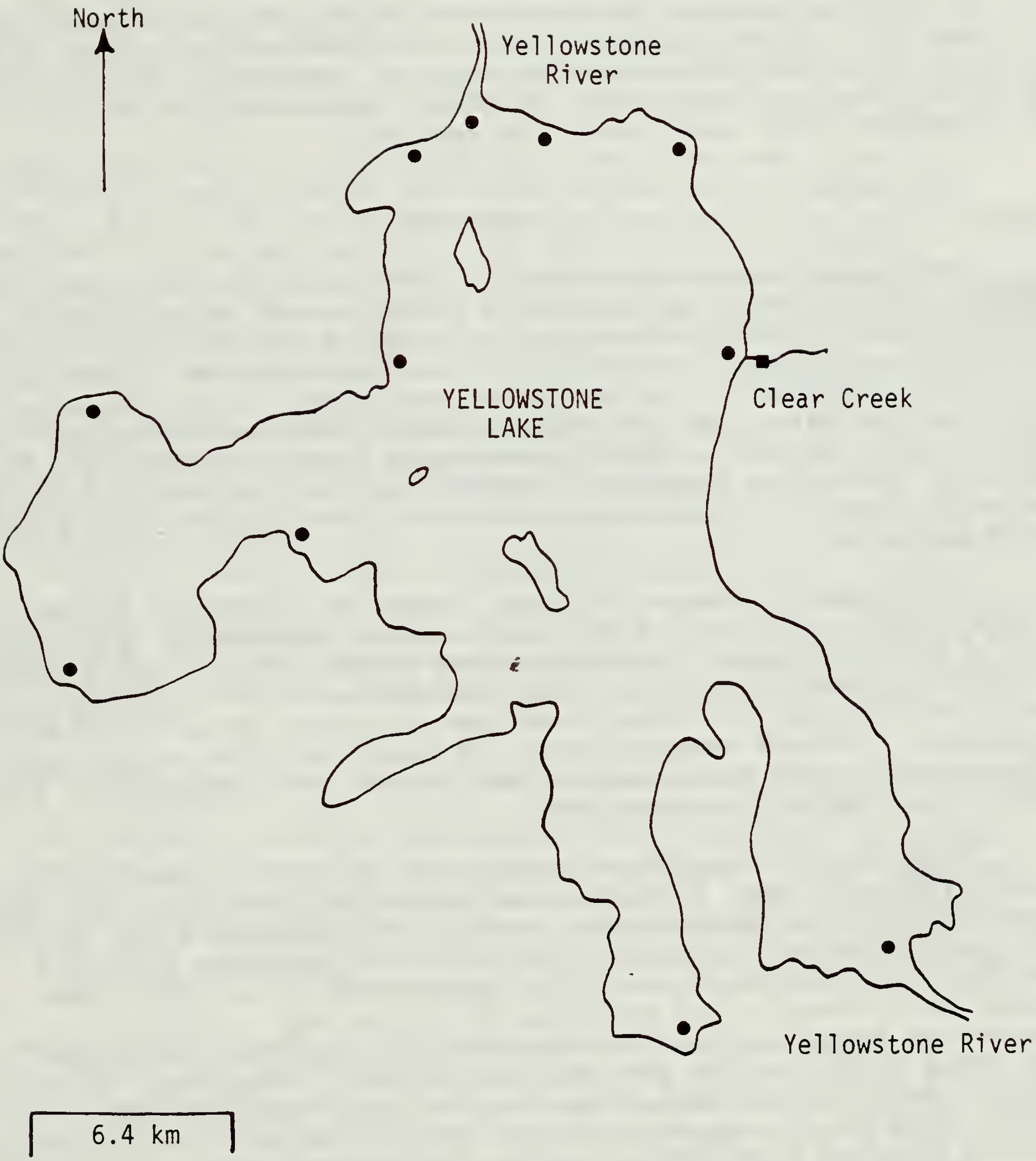


FIGURE 1.-Yellowstone Lake showing gillnetting sites (●) and the Clear Creek fish trap (■).

Clear Creek

Clear Creek originates 2,585 m above mean sea level on the western slope of the Absaroka Mountains and flows west for nearly 20 km before reaching the northeast shore of Yellowstone Lake (Figure 1). Discharge may reach 6.7 m^3/s during spring runoff, but drops to about 0.5 m^3/s by August. Adfluvial cutthroat trout from Yellowstone Lake spawn in Clear Creek and its 18 km of tributaries from late April through July.

Methods

Data sources.-Manned creel surveys and the Volunteer Angler Report (VAR) system (a voluntary postal creel survey) provided information on the Yellowstone Lake sport fishery for the years 1969 through 1991. Operation of the fish trap at Clear Creek provided information on adfluvial cutthroat trout spawners from Yellowstone Lake, and 29 years of data were available for the period 1945 to 1991. The largemesh gillnetting study provided data on cutthroat trout and longnose sucker populations from several areas of Yellowstone Lake for 20 of the 23 years between 1969 and 1991.

Field procedures.-The Clear Creek spawning run is monitored between May and July. Each year, stream discharge is measured by the midsection method (Buchanan and Somers 1969), and a stage-discharge relationship is developed (Linsley et al. 1982); mean-daily discharges are then predicted from the resultant best-fit equation. Stream temperatures are measured with a hand-held thermometer, and daily maxima and minima are averaged to estimate mean-daily water temperatures.

Before 1989, the "upstream trap" (i.e., the section of weir that fish must pass through when migrating upstream) was operated between 0800 and 2000 hours, and the "downstream trap" was operated between 0800 and 2400 hours. Electronic counters (Pulsar Electronics Model 550), which have been used since 1989, allow both traps to be operated 24 h per day. Counts of cutthroat trout moving through the upstream and downstream traps are made daily during the spawning season. Each day, a maximum of 75 trout are collected by dip net from the upstream trap, identified to sex, evaluated for spawning condition, and measured to the nearest 5 mm total length. Each week, an additional 100 trout are collected by dip net from the upstream trap, identified to sex, evaluated for spawning condition, measured to the nearest 1 mm total length, and weighed to the nearest 2 g; scales from fish in a subsample are collected for age-growth analyses. Similar daily and weekly sampling procedures for trout moving through the downstream trap have been followed in most years.

Largemesh gillnetting is conducted during a 5-d period in the third week of September, and 11 sites (Figure 1) are sampled annually. At each site, five Swedish experimental gill nets are set between 1300 and 1500 hours and retrieved the following day between 0800 and 1000 hours; these monofilament nets are 38 m long, 1.5 m deep, and have five 7.6-m-long graduated-mesh panels of 19, 25, 32, 38, and 51 mm (bar measure). Nets are set perpendicular to the shoreline (smallest mesh closest to shore) in water about 1.5 m deep at the nearshore end of the net and 4.6 m deep at the offshore end. Spacing between nets is about 100 m.

Captured fish are separated by site, net, and species; individuals of each species are then sorted from longest to shortest. Each fish is measured to the nearest 1 mm total length and weighed to the nearest 2 g. On the basis of gonadal examination, each fish is identified to sex and assigned a stage of maturity (Jones et al. 1979). Scales for age-growth analysis are collected from every third cutthroat trout. The presence of the tapeworm *Ligula intestinalis* is noted for longnose suckers.

Data analysis.-Sport-fishery data from manned creel surveys and the VAR system include annual estimates of angler effort (hours of fishing), mean landing rate (average number of trout landed per hour of fishing), angler-caused mortality (number of trout creeled plus an assumed 10% hooking mortality of released fish), and mean total length of angler-landed trout. Annual estimates of Proportional Stock Density (PSD) and Relative Stock Density (RSD; Gabelhouse 1984) of angler-landed trout were also examined; "stock," "quality," and "preferred" lengths used for calculating PSD and RSD estimates for cutthroat trout were 254, 356, and 406 mm.

Data from the Clear Creek fish trap operation include annual counts of cutthroat trout passing through the upstream trap and annual estimates of mean total length, PSD, and RSD for these fish. Annual estimates of mean age of cutthroat trout passing through the upstream trap were also analyzed; ages of sampled trout were estimated by the scale method (Bagenal and Tesch 1978), and mean ages for sample-groups of trout were estimated from an age-length key (Westrheim and Ricker 1978).

Largemesh gillnetting data were partitioned into four categories for analysis. Initially, annual estimates of relative abundance (mean number captured per net), mean total length, PSD, and RSD were made separately for cutthroat trout and longnose suckers; stock, quality, and preferred lengths for longnose suckers were 254, 406, and 457 mm. Subsequently, for cutthroat trout and longnose suckers classified as "prespawners" (i.e., fall-captured fish that, based on gonadal examination, apparently will spawn the following spring), annual estimates of relative abundance and mean total length were made for each species.

Results

Cutthroat Trout (1991)

Sport fishery.-On Yellowstone Lake in 1991, an estimated 53,000 anglers accounted for 153,900 angler days (38% of parkwide angler use) and 426,300 h of angler effort. Anglers landed an estimated 446,300 Yellowstone cutthroat trout and creeled about 37,500 of these fish; total estimated angler-caused mortality was 77,300 trout. Estimated mean-annual landing and creel rates were 1.04 and 0.09 fish/h, and estimated mean length of landed fish was 392 mm. Approximately 85% of the anglers who fished the lake were satisfied with their overall fishing experience; 77% were satisfied with numbers of fish landed, and 82% were satisfied with sizes of fish landed. Mean angling expertise was 1.8 (slightly less than experienced).

Clear Creek spawning run.-The Clear Creek spawning run was monitored from 16 May through 31 July in 1991.

Estimated mean-daily discharge was 1.23 m^3/s when the trap was installed on 16 May. Flows increased over the next 9 d in response to rapid snowmelt and fluctuated around 5.34 m^3/s between 5 and 13 June. Subsequently, flows declined and reached a low of 0.54 m^3/s by the end of July (Figure 2).

Mean-daily water temperatures were relatively cold during May and June. During the last 2 weeks of May, temperatures never exceeded 5°C and only rose to about 6°C by the last week of June. Water temperatures increased more rapidly during July and reached 13°C by the end of the month (Figure 2).

Just over 28,400 cutthroat trout passed through the upstream trap. Approximately 85% of the upstream migration occurred between 18 June and 22 July (Figure 3). As is usual at Clear Creek, substantial increases in the number of upstream migrants coincided with decreasing streamflow and increasing water temperature.

Based on the daily and weekly samples of fish from the upstream trap (Table 4), mean total length of upstream migrants was 405 mm, and PSD and RSD estimates were 98 and 46%. Mean weight and condition (K) were 623 g and 0.93, and the male-to-female ratio was 0.62:1. Average length, weight, and condition of upstream migrants tended to decrease as the spawning run progressed (Table 4). Although scale samples were collected in 1991, age-growth analyses were not completed.

Nearly 20,300 cutthroat trout passed through the downstream trap. About 82% of the downstream migration took place between 5 and 29 July (Figure 3). Based on the difference in counts between upstream and downstream migrants, the instream mortality estimate was 29%. Because of a change in study design in 1991,

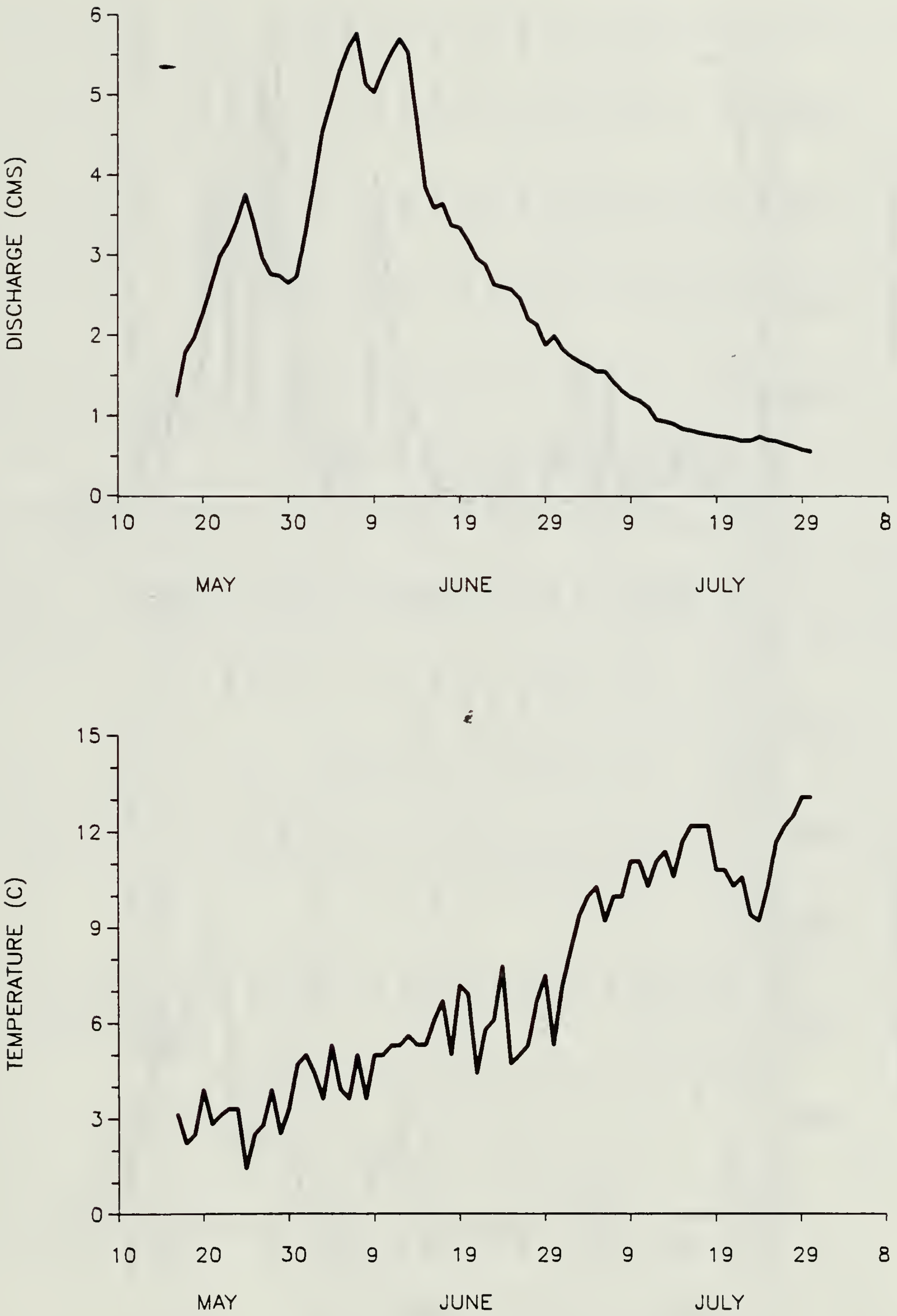
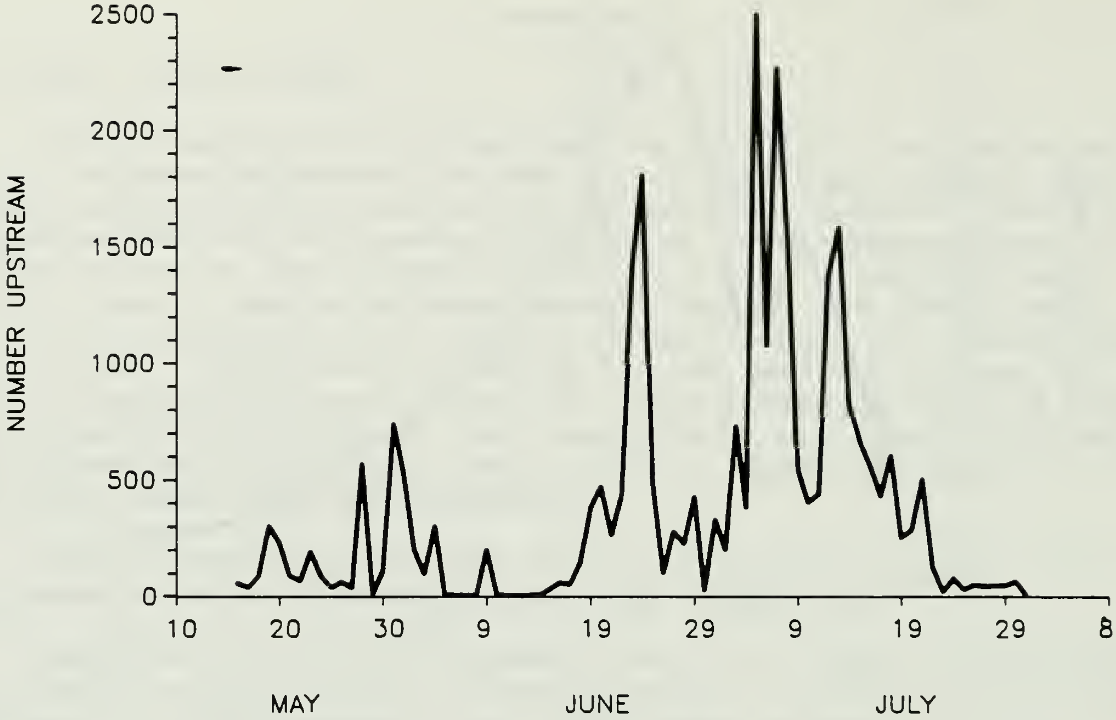


FIGURE 2.-Estimated mean-daily discharge and mean-daily water temperature at Clear Creek, May-July 1991.



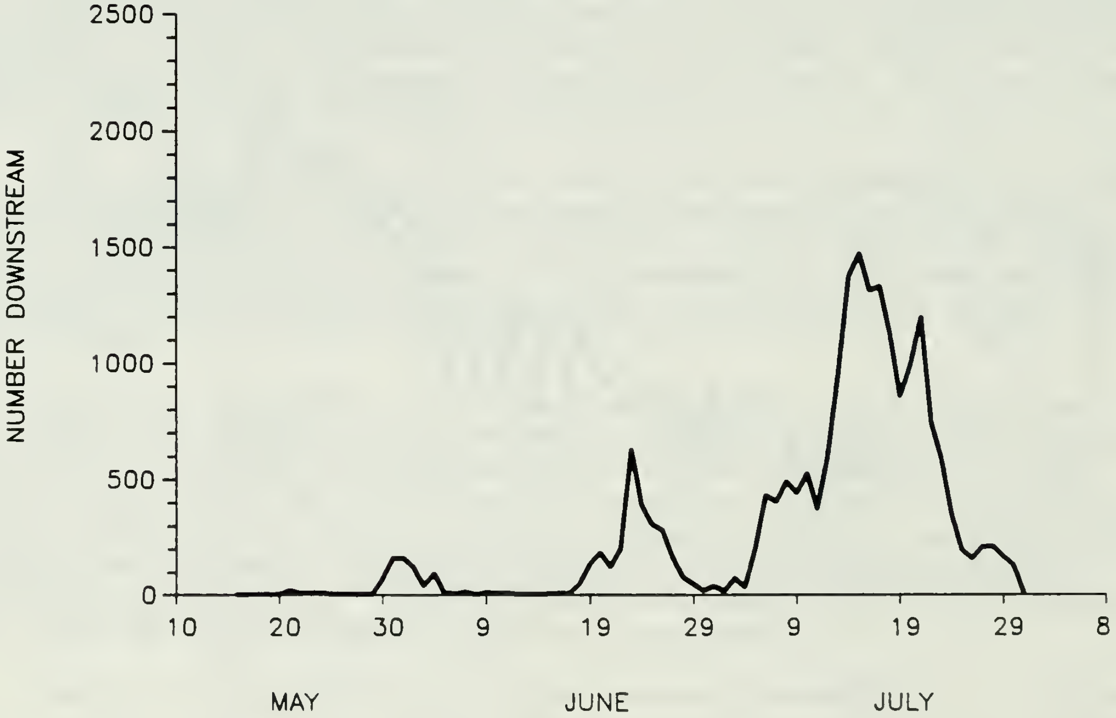


FIGURE 3.-Daily counts of adult cutthroat trout moving through the upstream and downstream traps at Clear Creek, May-July 1991.

TABLE 4.-Mean length[a], weight[b], and condition[b] of cutthroat trout sampled from the upstream trap at Clear Creek, for 1-week periods between 16 May and 31 July 1991.

		Males					Females					All trout (males, females, and unknown)					
Week	Dates	Mean length (mm)	N	Mean weight (g)	Mean condition (K)	N	Mean length (mm)	N	Mean weight (g)	Mean condition (K)	N	Mean length (mm)	N	Mean weight (g)	Mean condition (K)	N	Sex ratio
1	5/16-5/20	437	147	--	--	--	419	180	--	--	--	427	327	--	--	--	0.82:1
2	5/21-5/27	437	177	852	0.96	45	426	246	730	1.01	55	426	423	785	0.98	100	0.72:1
3	5/28-6/03	428	205	783	0.96	40	421	325	706	0.99	60	421	530	737	0.98	100	0.63:1
4	6/04-6/10	433	65	772	0.94	46	411	110	715	1.00	54	419	175	742	0.98	100	0.59:1
5	6/11-6/17	409	54	656	0.92	45	397	77	624	0.99	55	402	131	639	0.96	100	0.70:1
6	6/18-6/24	404	246	612	0.91	44	393	304	561	0.93	56	398	550	583	0.92	100	0.81:1
7	6/25-7/01	405	122	602	0.89	45	394	130	580	0.92	55	400	252	590	0.91	100	0.94:1
8	7/02-7/08	403	172	558	0.87	42	390	303	549	0.92	58	395	475	553	0.90	100	0.57:1
9	7/09-7/15	404	148	574	0.86	28	388	384	520	0.91	72	393	532	535	0.90	100	0.39:1
10	7/16-7/22	398	139	547	0.87	29	387	319	521	0.91	71	391	460	528	0.90	100	0.44:1
11	7/23-7/29	404	43	562	0.86	34	383	71	530	0.93	66	391	114	541	0.91	100	0.61:1
12	7/30-7/31	409	7	578	0.84	7	393	7	468	0.77	7	401	14	523	0.80	14	1:1
13	large fish	513	2	1,337	0.99	2	--	--	--	--	--	513	2	1,337	0.99	2	--
Composite	5/16-7/31	415	1,527	663	0.91	407	399	2,456	597	0.95	609	405	3,985	623	0.93	1,016	0.62:1

[a] Weekly mean lengths and composite mean lengths based on all fish sampled for "length-only" and "length-and-weight" during each week of the spawning season.
[b] Weekly mean weights and conditions and composite mean weights and conditions based on all fish sampled for "length-and-weight" during each week of the spawning season.

insufficient numbers of downstream migrants were sampled to describe length-structure characteristics of the downstream run.

Grizzly bear *Ursos arctos horribilis* sightings and signs of bear predation on spawning trout were common at the Clear Creek fish trap in 1991. Relatively high numbers (100-200) of white pelicans *Pelecanus erythrorhynchos* were also observed preying on trout at the mouth of the creek. Other wildlife commonly seen near the trap were mink *Mustela vison*, common loon *Gavia immer*, common merganser *Mergus merganser*, California gull *Larus californicus*, osprey *Pandian haliaetus*, bald eagle *Haliaeetus leucocephalus*, and great blue heron *Ardea herodias*.

Largemesh gillnetting.-In 1991, 777 cutthroat trout were caught (mean, 14.1 trout/net; Table 5) by gillnetting. Mean length of trout captured was 297 mm, and PSD and RSD estimates were 67 and 27%. Based on a subsample of 773 of these fish, mean weight and condition (K) were 318 g and 0.92.

Twenty-three percent of trout captured in 1991 were classified as prespawners (Table 5). Prespawner mean length, weight, and condition (K) were 397 mm, 612 g, and 0.95. The prespawner male-to-female ratio was 0.69:1. Average length of prespawner males (406 mm) was significantly greater (*t*-test;$P < 0.05$) than that of prespawner females (390 mm).

Cutthroat Trout (Long-term trends)

Sport fishery (1969-1991).-Estimated annual angler effort on Yellowstone Lake ranged from 368,000 to 426,000 h between 1969 and 1991. Although there was no obvious trend for the entire 22-year period, effort has risen steadily over the past 7 years. The 1991 estimate of 426,000 h is the highest on record (Figure 4).

An increasing trend was evident for estimates of mean-annual landing rate over the past 22 years. Most of the increase occurred when mean-annual landing rate rose from 0.5 trout/h in 1969 to 1.1 trout/h in 1975. Since then, mean-annual landing rate has been stable at about 0.9 trout/h (Figure 4).

A decreasing trend in estimated angler-caused mortality of cutthroat trout was evident between 1969 and 1991. Most of the decrease occurred when estimated angler-caused mortality dropped from 155,000 trout in 1969 to 66,000 trout in 1983. Since then, estimates of angler-caused mortality have varied between 57,000 and 83,000 trout per year (Figure 4).

Length-structure data from angler-landed trout were available for the years 1973 through 1991. During this 19-year period, mean length of landed trout increased from about 350 mm between 1973 and 1976 to a record high of 392 mm in 1991.

TABLE 5.-Length frequency and mean length, weight, and condition of cutthroat trout and longnose suckers captured in largemesh gill nets, Yellowstone Lake, 1991.

Species		Number captured in 50-mm length intervals									Total number			Mean condition
		100	150	200	250	300	350	400	450	500	captured	Mean length (mm)	Mean weight (g)	(K)
Cutthroat trout	Prespawner[a] males			2	1	2	20	39	10		74	406	676	0.97
	Prespawner females					11	52	39	6		108	390	568	0.94
	Nonspawners	1	141	177	98	43	77	53	5		595	267	227[b]	0.91[b]
	All trout	1	141	179	99	56	149	131	21		777	297	318[c]	0.92[c]
Longnose sucker	Prespawner males			2	38	37	20	41	12		150	356	635	1.27
	Prespawner females				1	4	9	62	62	16	154	450	1,372	1.16
	Nonspawners		57	140	53	26	1	3			280	233	169	1.16
	All suckers		57	142	92	67	30	106	74	16	584	322	527	1.19

[a] Prespawners are fall-captured fish that, based on examination of gonads, will spawn the following spring.
[b] Mean weight and condition of nonspawner trout are based on a subsample of 591 fish.
[c] Mean weight and condition of all trout are based on a subsample of 773 fish.

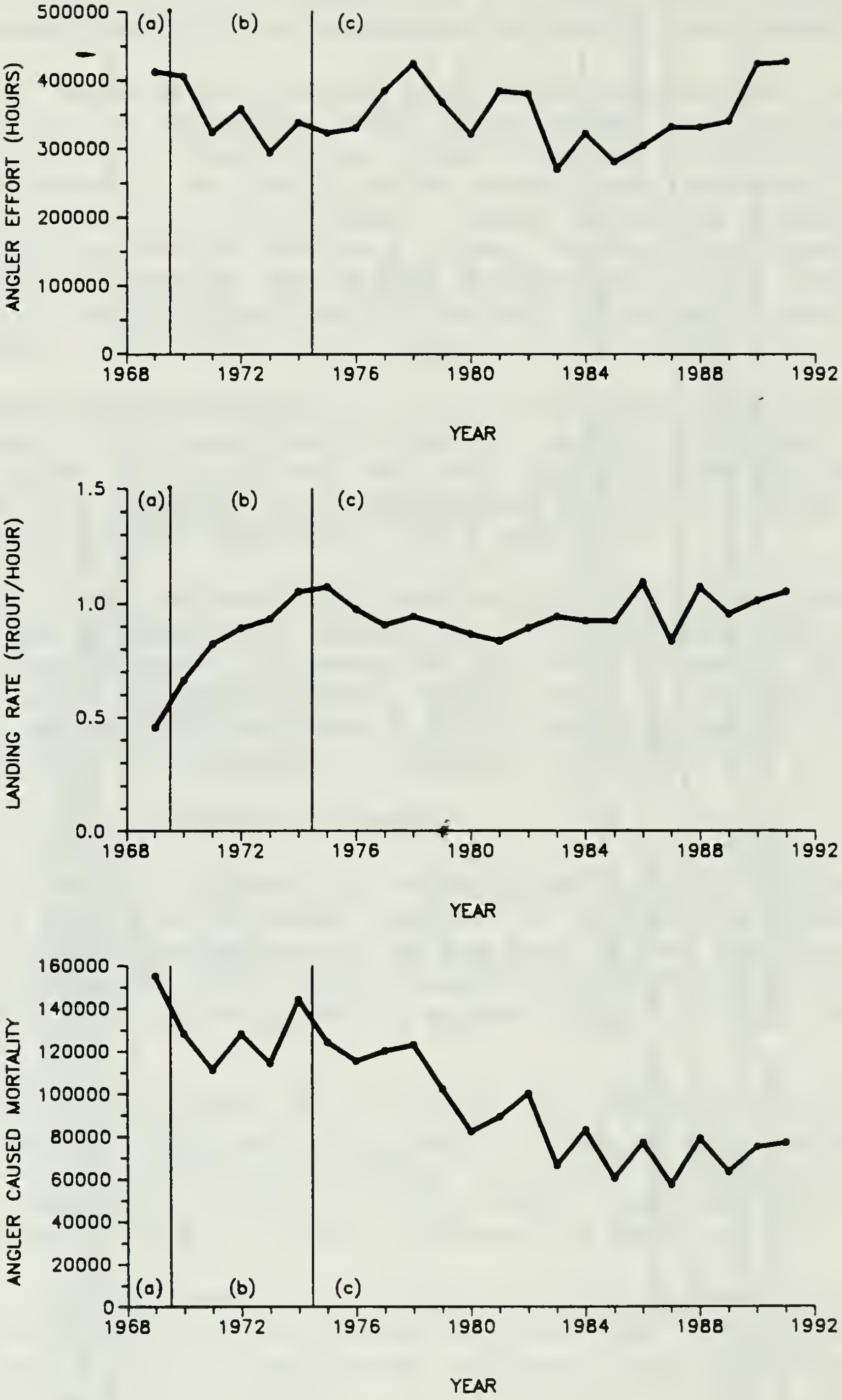


FIGURE 4.-Estimates of angler effort, mean landing rate, and angler-caused mortality for cutthroat trout from Yellowstone Lake, 1969 to 1991. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356 mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1991, 330 mm maximum size limit and two-trout-day creel limit.

Proportional Stock Density estimates, which ranged from 47 to 54% between 1973 and 1976 and have been increasing since then, reached a record high of 80% in 1991. Similarly, RSD estimates increased from about 8% between 1973 and 1976 to a record high of 36% in 1991 (Figure 5).

Clear Creek spawning run (1945-1991).-Between 1945 and 1991, the number of cutthroat trout annually counted through the upstream trap at Clear Creek ranged from 3,000 to 71,000 (Figure 6). Counts never exceeded 24,000 prior to 1961, and a decline was evident between 1957 and 1961. The number of upstream migrants apparently rose from 1962 to 1976, although there were only 3 years of data on which to base this conclusion. Since 1977, counts of upstream migrants have varied between 28,000 and 71,000 per year.

Mean length of cutthroat trout caught by dip net from the upstream trap ranged from 365 to 405 mm between 1953 and 1991 (Figure 7). Substantial increases in mean length occurred from 1959 through 1961 and from 1984 through 1991. The mean length of 405 mm for 1991 is the highest on record.

Proportional Stock Density and RSD estimates were available for only 18 of the 31 years between 1961 and 1991 (Figure 7). Proportional Stock Density and RSD estimates were lowest in the mid-1960s (66 and 4%, respectively), and the increasing trend that began in the late 1970s has continued into 1991. The 1991 PSD and RSD estimates of 98 and 46% are the highest on record.

Estimated mean age of cutthroat trout caught by dip net from the upstream trap ranged from 3.9 to 6.1 years among the 17 years of data available between 1945 and 1991 (Figure 7). Before 1973, estimated mean age never exceeded 4.5 years. The rising trend in estimated mean age that began in 1977 continued through 1990. The estimated mean age of 6.1 years for 1990 is the highest on record.

Largemesh gillnetting (1969-1991).-Between 1969 and 1991, the mean number of cutthroat trout captured per net ranged from 10.6 to 19.5, and mean length of captured trout fluctuated between 281 and 330 mm. During this same period, PSD estimates varied between 32 and 68%, and RSD estimates ranged from 1 to 26% (Figure 8). Increases in the mean number of trout captured per net occurred from 1969 to 1977 and from 1987 through 1989. There were no obvious trends in the mean length of captured trout during the past 23 years; however, PSD estimates have been increasing since 1977, and RSD estimates have been rising since 1979.

Since 1969, mean number of cutthroat trout prespawners captured per net has ranged from 3.2 to 5.6, and mean length of captured prespawners has fluctuated between 350 and 400 mm (Figure 9). There have been no clear trends in the mean number

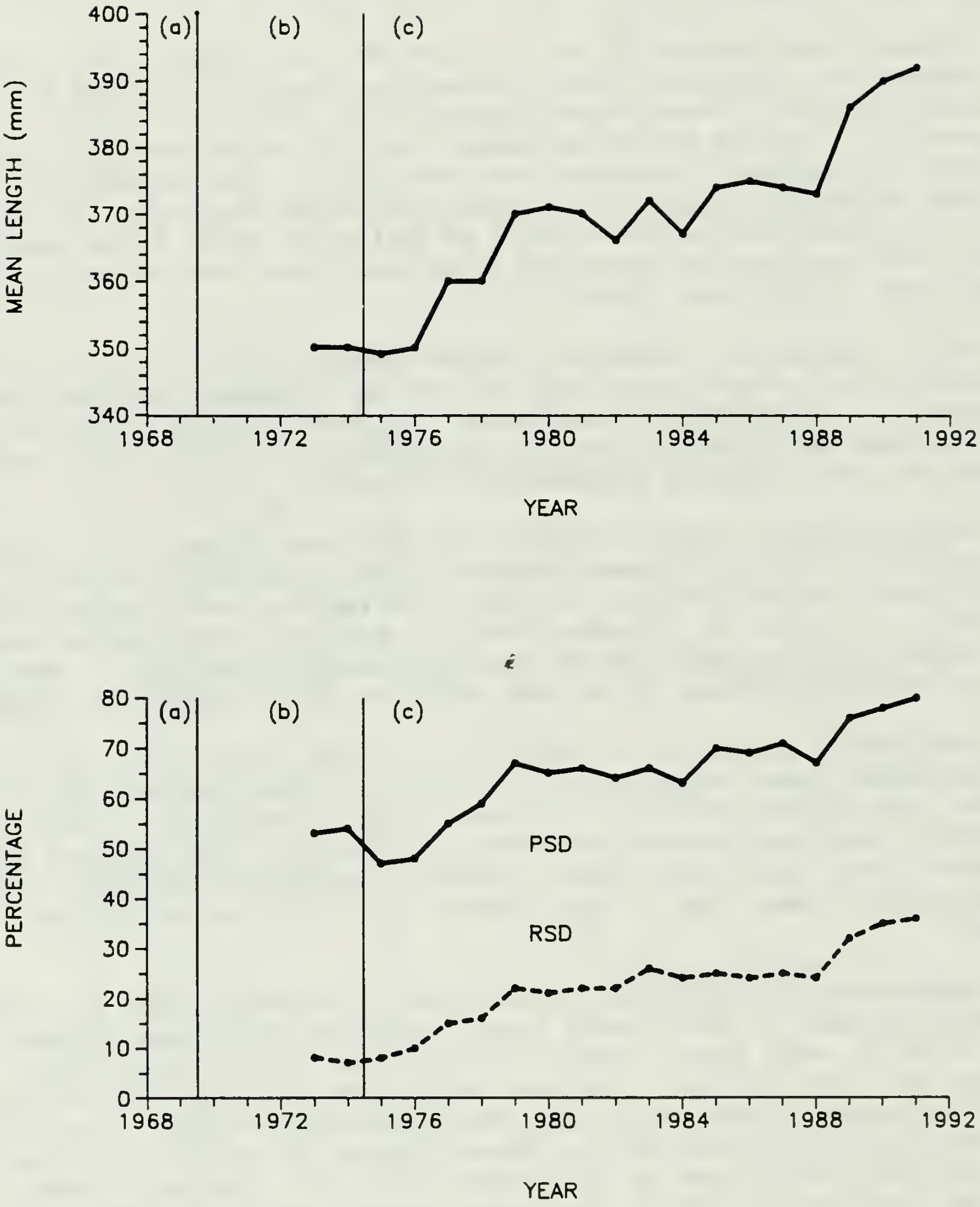


FIGURE 5.-Estimates of mean length, Proportional Stock Density (PSD), and Relative Stock Density (RSD) for angler-landed cutthroat trout from Yellowstone Lake, 1973 to 1991. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356 mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1991, 330 mm maximum-size limit and two-trout-per-day creel limit.

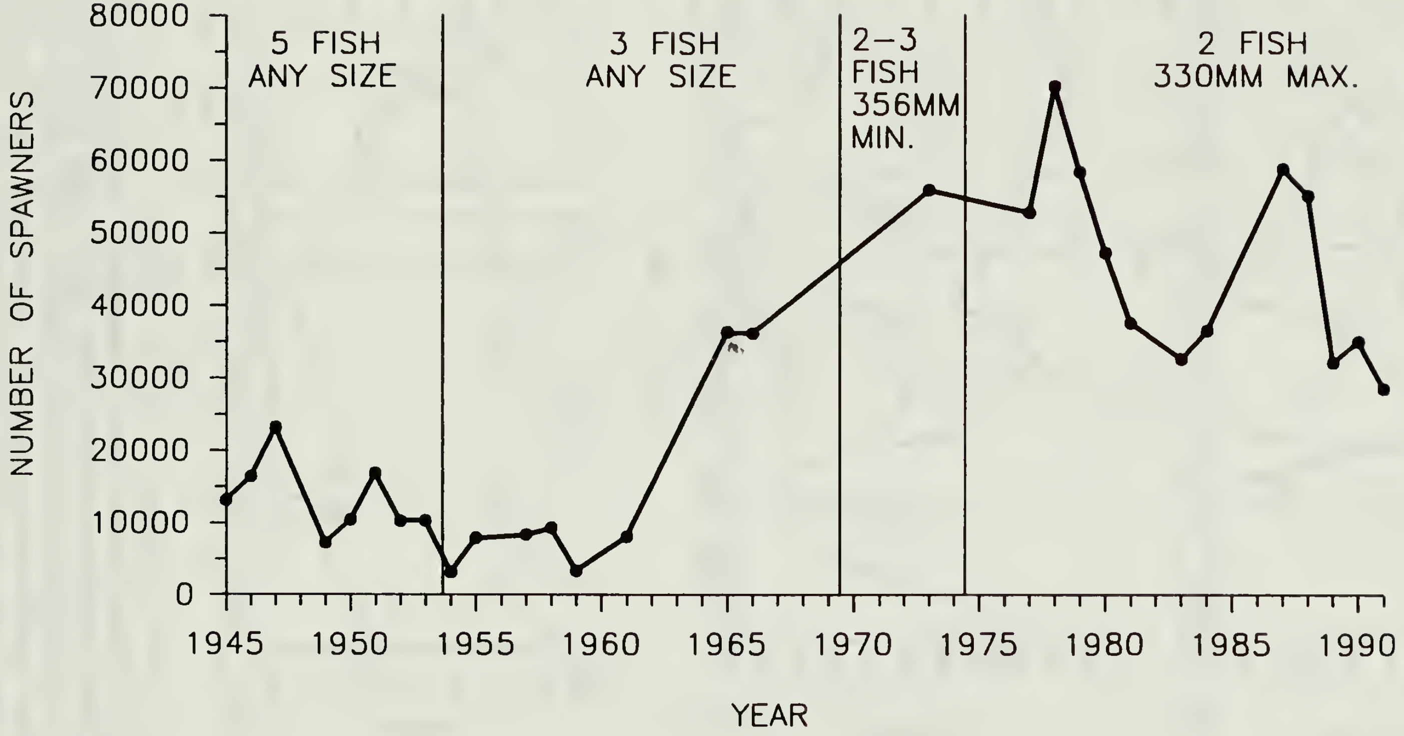


FIGURE 6.-Number of cutthroat spawners counted through the upstream trap at Clear Creek, 1945 to 1991.

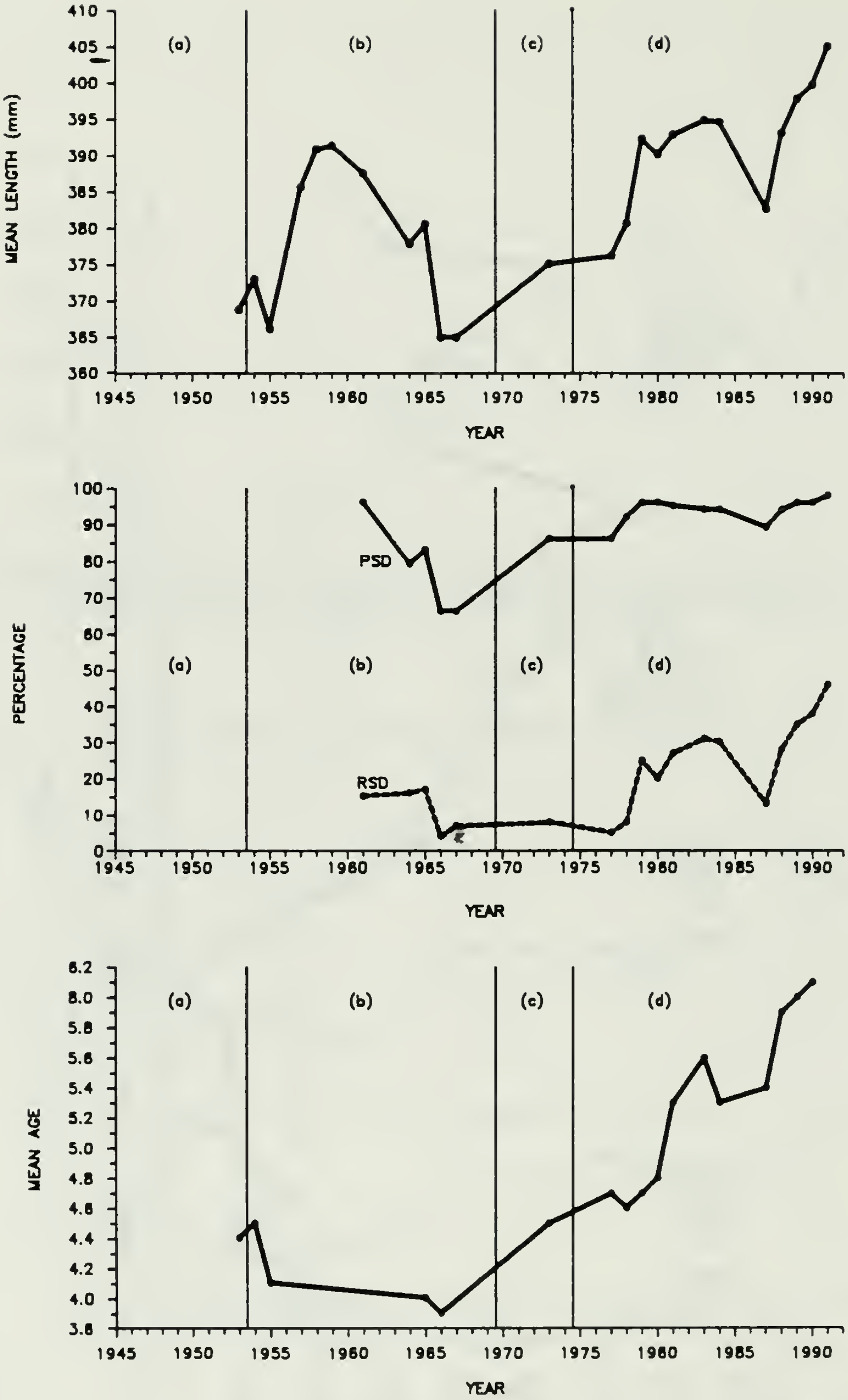


FIGURE 7.-Estimates of mean length, Proportional Stock Density (PSD), Relative Stock Density (RSD), and mean age for cutthroat trout sampled from the upstream trap at Clear Creek, 1953 to 1991. Angling regulations: (a) 1953, no size limit and five-trout-per-day creel limit; (b) 1954 to 1969, no size limit and three-trout-per-day creel limit; (c) 1970 to 1974, 356 mm minimum-size limit and two- or three-trout-per-day creel limit; (d) 1975 to 1991, 330 mm maximum-size limit and two-trout-per-day creel limit.

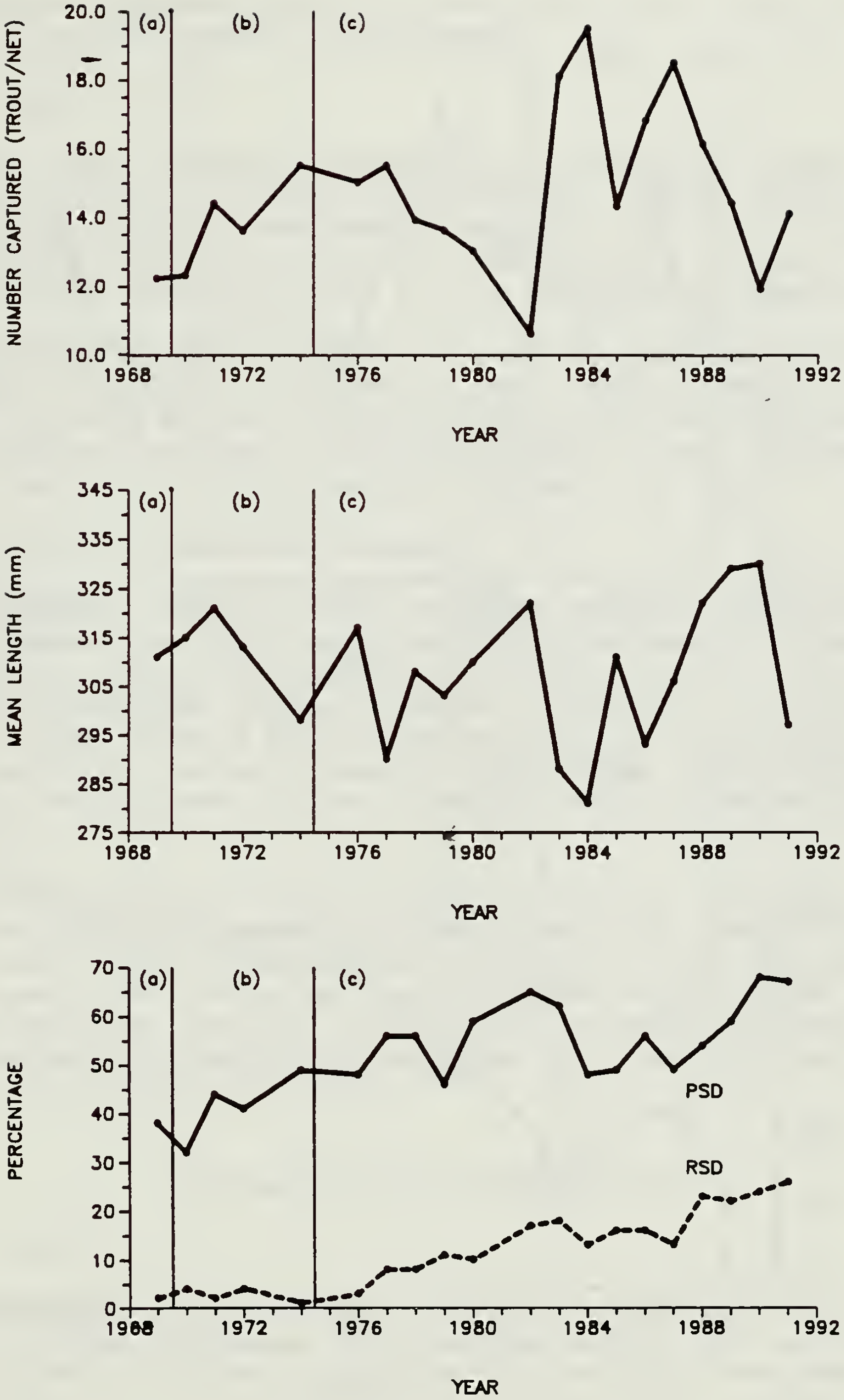


FIGURE 8.-Relative abundance index, mean length, Proportional Stock Density (PSD) estimates, and Relative Stock Density (RSD) estimates for cutthroat trout captured in experimental largemesh gill nets, Yellowstone Lake, 1969 to 1991. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356 mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1991, 330 mm maximum-size limit and two-trout-per-day limit.

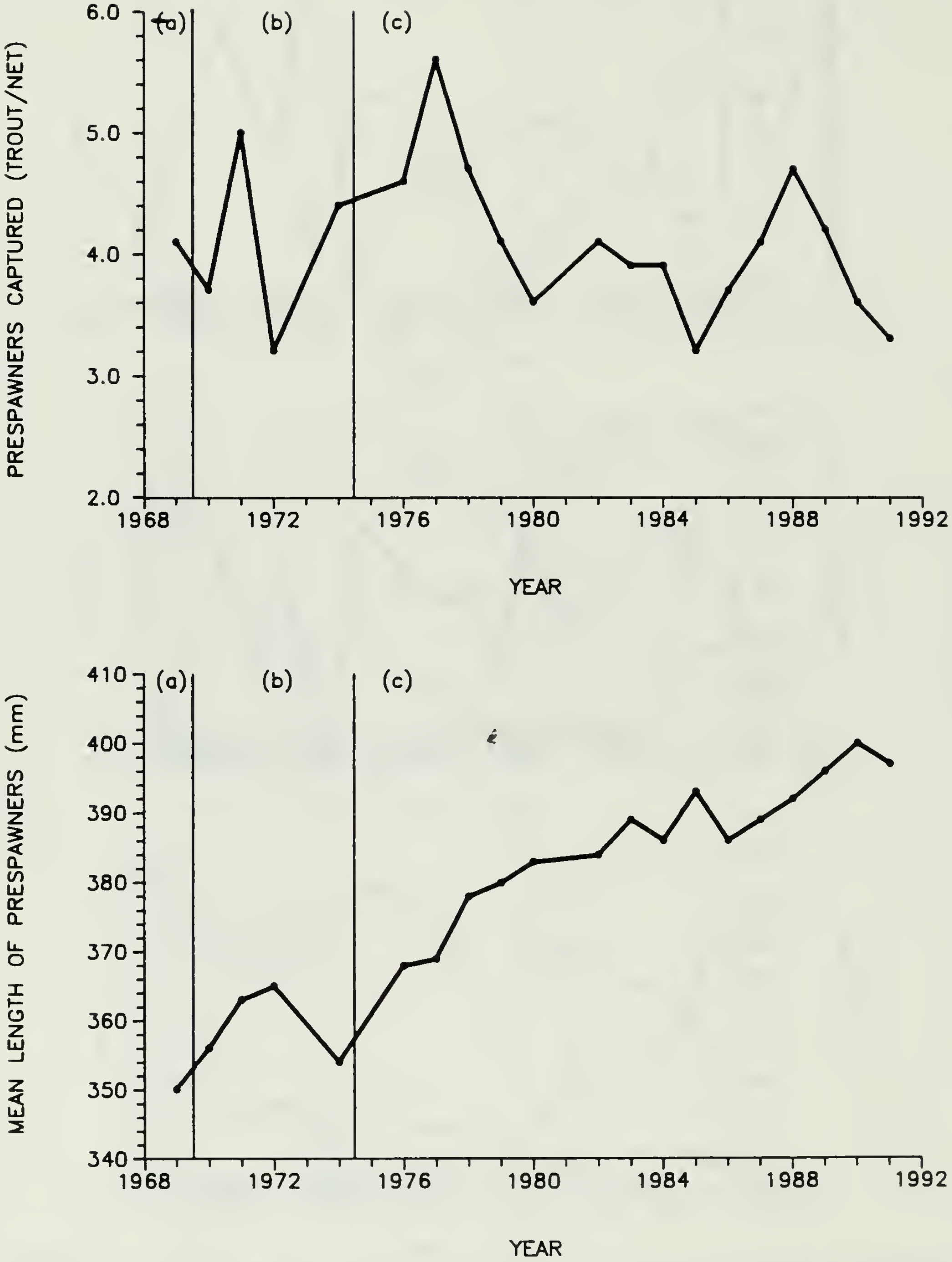


FIGURE 9.-Relative abundance index and mean length for cutthroat trout prespawners captured in experimental largemesh gill nets, Yellowstone Lake, 1969 to 1991. Angling regulations: (a) 1969, no size limit and three-trout-per-day creel limit; (b) 1970 to 1974, 356 mm minimum-size limit and two- or three-trout-per-day creel limit; and (c) 1975 to 1991, 330 mm maximum size limit and two-trout-per-day creel limit.

of prespawners captured per net; however, mean length of prespawners has increased considerably.

Longnose Sucker (1991)

In 1991, 584 longnose suckers were captured (mean, 10.6 suckers/net) during largemesh gillnetting. Mean length was 322 mm, and PSD and RSD estimates were 49 and 19%. Average weight and condition (K) were 527 g and 1.19. *Ligula intestinalis* was present in 2% of the longnose suckers captured.

Approximately 52% of captured suckers were classified as prespawners (Table 5). Prespawner mean length, weight, and condition (K) were 404 mm, 856 g, and 1.21. Average length of prespawner males (356 mm) was significantly less (*t*-test; $P < 0.01$) than that of prespawner females (450 mm).

Longnose Sucker (Long-term trends)

Between 1969 and 1991, the average number of longnose suckers captured per gill net fluctuated between 2.6 and 37.0, and mean length ranged from 316 to 401 mm. During this same period, PSD estimates varied between 24 and 65%, and RSD estimates ranged from 6 to 22% (Figure 10). There were no obvious trends in the mean number of suckers captured per net, mean length, or PSD estimates; however, RSD estimates have been increasing since 1982.

For prespawner longnose suckers captured by gillnetting between 1969 and 1991, average number per net ranged from 1.4 to 20.4, and mean length fluctuated between 377 and 420 mm (Figure 11). Although there were no clear trends in the mean length of prespawner suckers captured during this 23-year period, a drop in the mean number of prespawner suckers captured per net that began in 1977 has continued into 1991.

Discussion and Conclusions

Cutthroat Trout

Length-structure data from the sport fishery, Clear Creek spawning run, and largemesh gillnetting study and age data from the Clear Creek spawning run indicate that the increase in the relative abundance of large, old cutthroat trout noted by Gresswell and Varley (1988) for the period 1975-1986 and by Jones et al. (1976-1990) for the period 1975-1990 has continued into 1991. How long this positive trend will last may in part depend on future trends in angler-caused mortality. If angler-caused mortality increases substantially and negatively affects trout population structure, the current daily limit of two fish ≤330 mm long may have to be adjusted to ensure adequate protection for the Yellowstone cutthroat trout stocks of Yellowstone Lake.

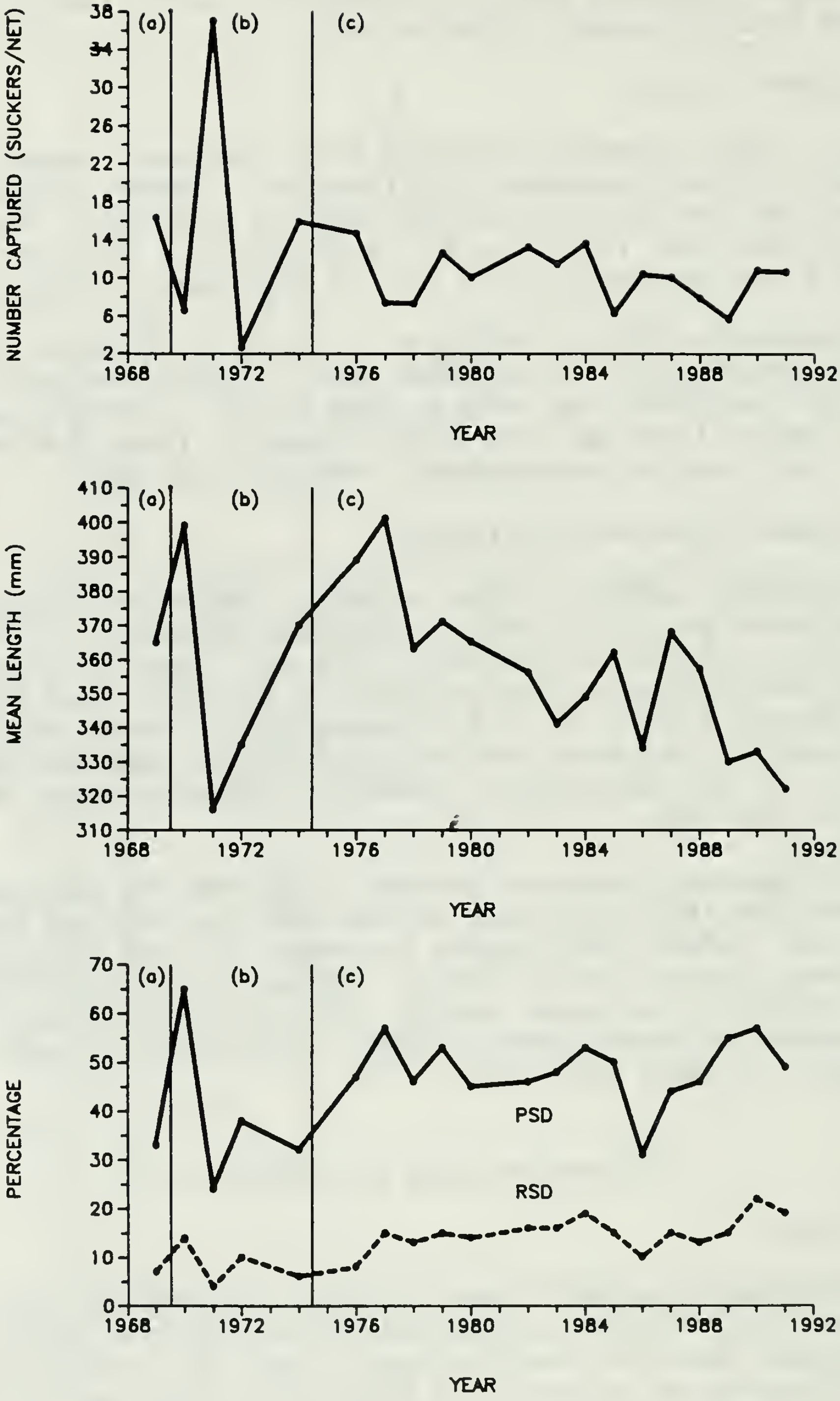


FIGURE 10.-Relative abundance index, mean length, Proportional Stock Density (PSD) estimates, and Relative Stock Density (RSD) estimates of longnose suckers captured in experimental largemesh gill nets, Yellowstone Lake, 1969 to 1991. Angling regulations for cutthroat trout: (a), (b), and (c) 1969 to 1991, five fish of any size.

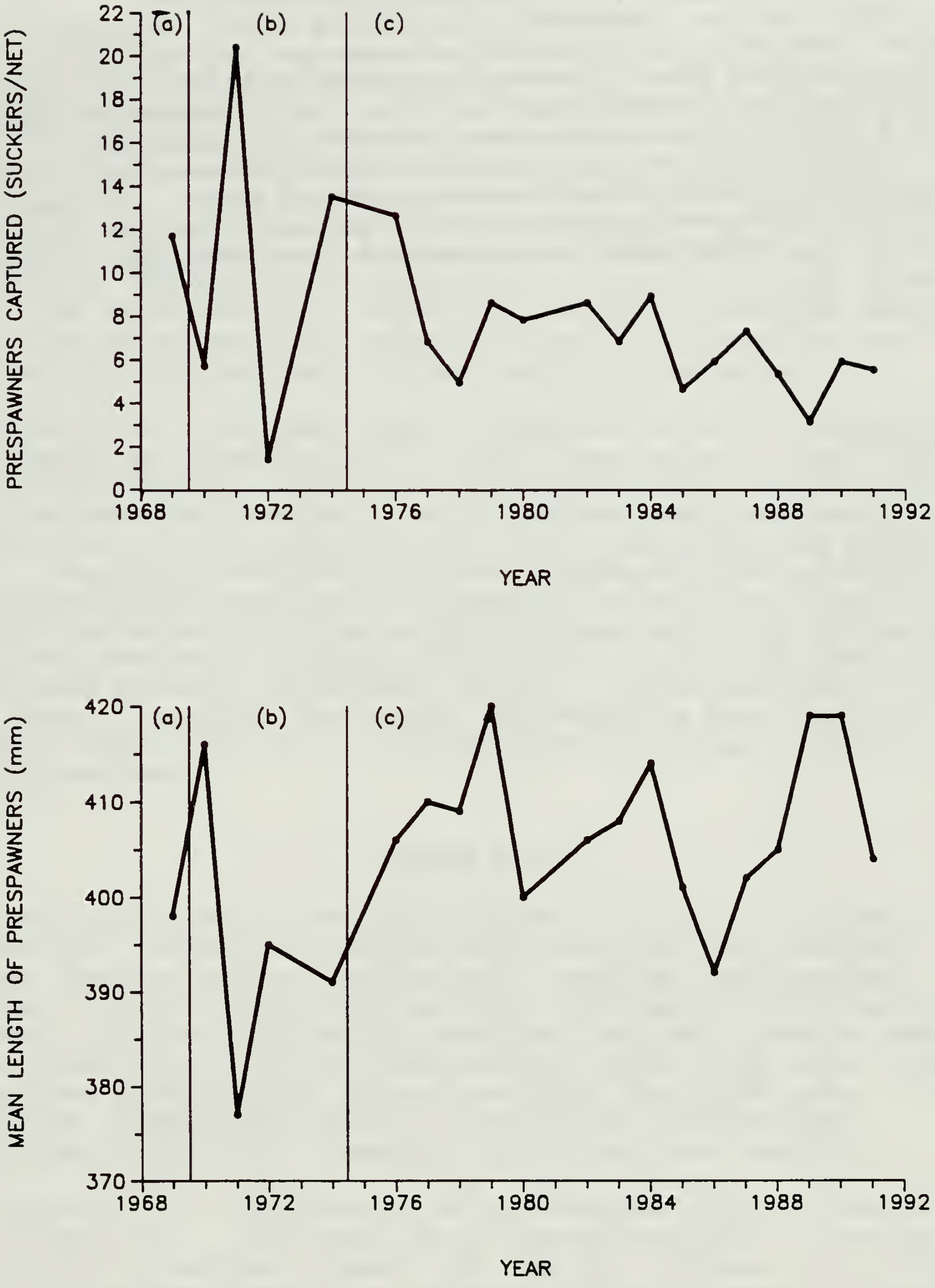


FIGURE 11.-Relative abundance index and mean length of longnose sucker prespawners captured in experimental largemesh gill nets, Yellowstone Lake, 1969 to 1990. Angling regulations: (a), (b), and (c) 1969 to 1991, five fish of any size.

Longnose Sucker

Data from the largemesh gillnetting study suggested that the relative abundance of longnose suckers ≥457 mm long increased between 1969 and 1991. Because longnose suckers are rarely caught by anglers in Yellowstone Lake, it is probable that the change has occurred in response to factors independent of the sport fishery. It is also possible that the observed change is independent of interactions with cutthroat trout, because longnose suckers and cutthroat trout probably do not compete spatially or temporally in Yellowstone Lake (Gresswell and Varley 1988).

LAKE AREA-BRIDGE BAY CUTTHROAT TROUT SPAWNING AND ASSOCIATED BEAR ACTIVITY: 1989-1991

Conflicts between humans and wildlife are major concerns in Yellowstone National Park. Human-bear conflicts in the Lake Area (LA) and at Bridge Bay (BB) may occur from May through July when adfluvial Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* spawn in Yellowstone Lake tributaries and are preyed on by grizzly bears *Ursus arctos horribilis* and black bears *U. americanus*. The National Park Service (NPS) is attempting to minimize the potential for human-bear conflicts in the LA-BB area during the cutthroat trout spawning season by managing human use, and effective management requires accurate information on cutthroat trout spawning and bear activity patterns.

Cutthroat trout spawning tributaries in the LA-BB area have been identified (Hoskins 1974, 1975; Jones et al. 1986, 1987; Reinhart and Mattson 1986, 1987; Reinhart 1990), and data on the timing of spawning runs were collected between 1985 and 1988 (Jones et al. 1986, 1987; Reinhart 1990; Reinhart and Mattson 1990). Based on these studies and recommendations by the U.S. Fish and Wildlife Service, Interagency Grizzly Bear Study Team, and NPS, cutthroat trout spawning and bear activity patterns in the LA-BB area were monitored more intensively from 1989 through 1991 by NPS Resource Management staff. The objectives of this study were to monitor the timing and relative magnitude of cutthroat trout spawning runs and associated bear activity along spawning streams.

Study Area

The LA-BB area is on the northwest shore of Yellowstone Lake (Figure 12). Lake Area visitor services include a ranger station, general store, restaurants, lodging, and hospital. Government and concessioner employee housing is also located in the area. Bridge Bay visitor services include a ranger station, marina, general store, and campground. Sand Point is a developed picnic area with fishing access south of the LA-BB area. Popular LA-BB area recreational activities include sightseeing, picnicking, day hiking, boating, bicycling, and angling.

There are 15 tributaries of Yellowstone Lake in the LA-BB area (Figure 12). Cutthroat trout spawn annually in Stream 1204, Soldier Creek, Hatchery Creek, Stream 1200, Stream 1199, Wells Creek, and Bridge Creek. An elevated culvert prevents trout from ascending Hotel Creek, but trout occasionally spawn in the stream mouth. Spawning occurs in Weasel Creek in years when lake levels are high enough to allow access through the culvert under the Grand Loop Road. Stream 1191 occasionally supports a spawning run. The other five streams are not known to support spawning runs (Jones et al. 1986, 1987; Reinhart 1990).

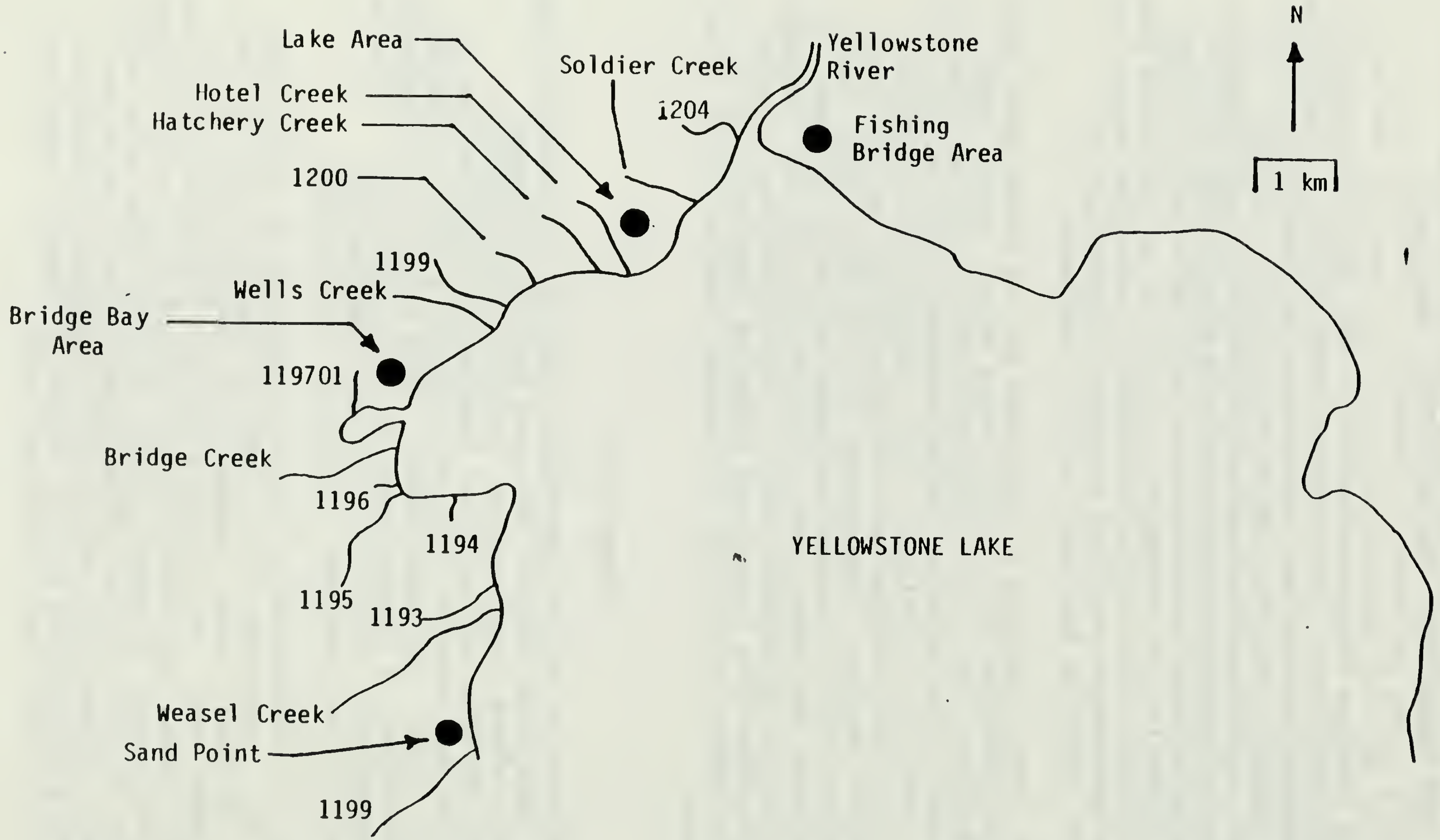


FIGURE 12.-Yellowstone Lake tributaries in the Lake Area and Bridge Bay area, Yellowstone National Park.

Methods

Sample sites and data base.-This report examines cutthroat trout spawning and bear activity data collected annually in the LA-BB area from 1989 through 1991. During this period, sampling was concentrated on cutthroat trout spawning streams near areas of high human use. In addition, Weasel Creek was sampled because a new campground has been proposed near this stream, and Stream 1191 was sampled in 1990 and 1991 because of recent bear activity near the Sand Point picnic area.

Field procedures.-Beginning 1 May in each year of the study, streams in the LA-BB area were checked daily to detect the presence of adult cutthroat trout. Once adult trout were found (i.e., onset of spawning), weekly visual counts of adult trout were used to estimate peak periods and relative magnitude of spawning runs. In each stream on each sample day, two people walked upstream from the stream mouth and recorded the number of adult trout observed. Weekly sampling continued until most adult trout had returned to the lake (i.e., end of spawning).

While making fish counts, observers recorded bear sign (e.g., sightings, fish parts, hair, scats, and tracks). Tracks and track measurements were used to determine the number, species, and association of family groups of bears (Reinhart 1990).

Results

1991

Cutthroat trout.-Evidence of predation on fish (e.g., fish parts) by unknown predators was found along Bridge Creek on 14 May; however, the earliest date on which adult trout were observed in LA-BB area streams was 28 May (two streams). The last date adult trout were found was 2 July (six streams; Figure 13). Weekly counts indicated that the largest spawning run occurred in Wells Creek, followed by Bridge Creek, Soldier Creek, Hatchery Creek, Stream 1199, Weasel Creek, Hotel Creek, and Stream 1191 (Figure 13).

A sand spit that usually blocks the mouth of Stream 1191 was opened periodically by wave action and stream current. Fish parts were first observed on the streambank on 11 June, but adult trout were first observed in the stream on 2 July. Some adult trout became stranded in early July when streamflow became intermittent. The spawning run in Stream 1191 was estimated to have lasted about 3 weeks.

Bears.-Bear sign and evidence of bear predation on spawning trout were found along most LA-BB spawning streams in 1991. Bear tracks (species unknown) were first observed along Stream 1199 on 7 May and along Soldier Creek on 14 May. Grizzly bear tracks

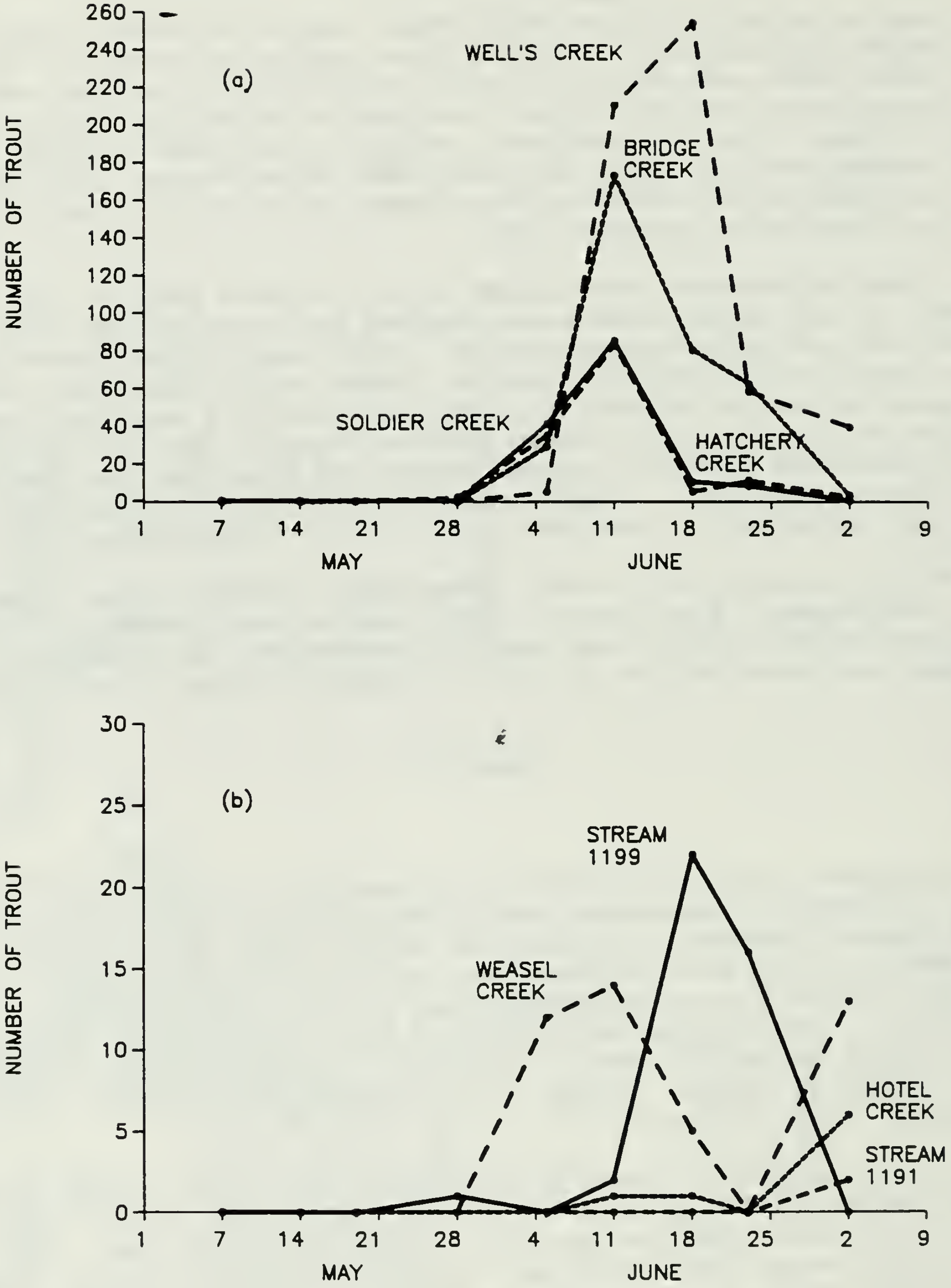


FIGURE 13.-Counts of cutthroat trout spawners in eight streams in the LA-BB area, 1991. (a) streams in which maximum counts of adult trout exceeded 90, and (b) streams in which maximum counts of adult trout were less than 90.

were first found along Wells Creek, Bridge Creek, and Weasel Creek on 14 May; subsequently, grizzly bear tracks were found along Soldier Creek (19 May), Hatchery Creek (28 May), Stream 1191 (11 June), and Stream 1199 (23 June). No bear tracks were observed along Hotel Creek in 1991; however, evidence of bear predation on spawning trout has been observed in previous years at the mouth of this creek (French and French 1990; Reinhart 1990). Track measurements made during fish surveys indicated that between 9 and 11 different bears (i.e., lone bears and family groups) used the LA-BB streams in 1991; nine were grizzly bears (one of these was a sow with a young bear about 2 years old), and two bears could not be identified to species.

Three-Year Trends (1989-1991)

Cutthroat trout.-Timing of cutthroat trout spawning in LA-BB area tributaries varied considerably during the past 3 years; spawning lasted 4 to 6 weeks in 1989 (mid May to late June), 4 to 8 weeks in 1990 (early May to early July), and 3 to 5 weeks in 1991 (late May to early July). Weekly counts of adult trout in each year of the study suggested that the largest spawning runs occurred in Bridge, Wells, Hatchery, and Soldier creeks; spawner access to these four streams is not seriously hampered by road culverts. Spawner access to Weasel and Hotel creeks, however, is severely restricted or blocked by road culverts. Stream 1191 and Stream 1199 are small streams that probably have little suitable spawning substrate. Lack of data from Stream 1200 and Stream 1204 precluded comparisons with the other eight LA-BB area spawning streams.

Bears.-Based on track analyses, the maximum number of bears (i.e., lone bears and family groups) using LA-BB area spawning streams increased from 5 in 1989 to 8 in 1990 to 11 in 1991. Track analysis also indicated that from one to five bears concurrently used a single spawning stream in 1990 and one to three bears concurrently used a single spawning stream in 1991. Observations of seasonal activity patterns revealed that, on most LA-BB area spawning streams, bear activity began at the peak of the spawning run, was highest after peak spawning, and declined thereafter. During the past 3 years, two grizzly bears were trapped and removed from the LA-BB area during the cutthroat trout spawning season.

Discussion

Cutthroat Trout

Timing of cutthroat trout spawning in LA-BB area streams, as in other Yellowstone Lake tributaries, appeared to be influenced by several environmental factors. Spawning usually began as high spring flows subsided, water clarity increased, and stream temperatures rose above 8°C. Factors affecting time of peak spawning are poorly understood, but spawning-run duration in

LA-BB area streams may be limited by interactions among low streamflow, natural blockage of the stream mouth by sand spits, and the ability of adult trout to pass through road culverts. Size of spawning runs in LA-BB area tributaries may be a function of spawner access to streams and availability of suitable spawning habitat.

Bears

Reinhart (1990) stated that the track-measurement method probably underestimated the number of bears using a spawning stream; thus, it is possible that the number of bears using LA-BB area spawning streams from 1989 through 1991 was greater than reported. Substrate suitable for identifying tracks was not always present along streams, and French and French (1990) observed that bears preying on fish often walked in the stream, thus reducing the presence of tracks.

Based on observed patterns of bear activity along Yellowstone Lake spawning streams, Reinhart (1990) concluded that bear predation on spawning trout was positively correlated with volumetric trout density. Trout densities are relatively high at, or just after, peak spawning and during intermittent streamflows when spawners become stranded in pools. Postspawning trout are usually in poor condition and vulnerable to predation.

Reinhart and Mattson (1990) found that bear use of Yellowstone Lake spawning streams within 1 km of park developments was less than expected despite sometimes high spawner densities. Bears using spawning streams near developments, however, may become habituated to humans. Habituation may result when the attraction to "natural" foods (e.g., spawning cutthroat trout) outweighs the tendency of bears to avoid humans, or when subdominant bears are displaced by dominant bears into areas of high human use. Adult female and subadult grizzly bears are more likely than other grizzly bears to forage closer to developments and become habituated (Mattson et al. 1987); consequently, these animals are more likely to be involved in management actions such as trapping and relocation (Mattson 1990).

Management Actions and Recommendations

Several management actions have been used by the NPS to reduce potential human-bear conflicts in the LA-BB area during the cutthroat trout spawning season. These include: 1) monitoring trout spawning and bear activity patterns; 2) closing areas near spawning streams to human use; 3) restricting human use of portions of the LA-BB and Sand Point Picnic areas; 4) delaying openings of lodging units and campgrounds; 5) educating visitors through brochures and the park newspaper; 6) eliminating early-season Lake Lodge conferences and meetings; 7) repairing the Transfer Station fence; 8) closing the Natural

Bridge Road (except for administrative use); and 9) trapping and relocating bears. These management actions should be reviewed and updated annually.

Because of annual variation in timing of cutthroat trout spawning runs and bear activity, it has been difficult to establish a "standard" date for the opening of LA-BB area visitor facilities. However, it is not prudent to allow unregulated human access to spawning areas. Data collected from 1989 through 1991 have been used to reduce the potential for human-bear conflicts in the LA-BB area during the cutthroat trout spawning season. It is recommended that the monitoring of cutthroat trout spawning and bear activity be continued in 1992.

GRANT VILLAGE CUTTHROAT TROUT SPAWNING AND ASSOCIATED BEAR ACTIVITY: 1986-1991

Adfluvial Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* spawn in Yellowstone Lake tributaries from May through July and are preyed on by grizzly bears *Ursus arctos horribilis* and black bears *U. americanus* (Hoskins 1974, 1975; Mealy 1975; Jones et al. 1986; Reinhart 1990). Bear predation on spawning trout in Yellowstone Lake tributaries in or near developed areas such as Grant Village creates potential conflicts between humans and bears. Since 1986, the National Park Service (NPS) has attempted to reduce the potential for human-bear conflicts at Grant Village during the cutthroat trout spawning season by managing human use, and effective management has required annual information on cutthroat trout spawning and bear activity. Objectives cooperatively established by the NPS, U.S. Fish and Wildlife Service, and Interagency Grizzly Bear Study Team were to monitor the timing and relative magnitude of cutthroat trout spawning runs and associated bear activity along spawning streams.

Study Area

Grant Village encompasses 3.75 km² adjacent to the West Thumb of Yellowstone Lake (Figure 14). Visitor services include a ranger station, visitor center, gas station, general store, restaurants, motel lodging, and a 418-site campground. Employee housing, a maintenance shop, and sewage and water treatment plants provide support for the visitor services. Camping, boating, sightseeing, picnicking, hiking, bicycling, and angling are popular recreational activities.

Five streams flow through Grant Village to Yellowstone Lake (Figure 14). Big Thumb Creek, bordering Grant Village on the north, is the largest and the only perennial stream in the area. Stream 1167 and Sandy Creek flow through the campground. Stream 1165 enters the lake east of the visitor lodging area. Sewer Creek borders Grant Village on the southeast and passes near a concessioner trailer court.

Methods

Data base and sample sites.-This report examines cutthroat trout spawning and associated bear activity data collected in Stream 1167, Sandy Creek, and Sewer Creek from 1986 through 1991; these streams were sampled annually because they flow through areas of high human use. Big Thumb Creek was sampled in 1986, but because virtually all cutthroat trout spawning in this stream was found to occur in areas not used extensively by humans, it was not sampled between 1987 and 1991. Stream 1165 was not sampled because previous studies (Hoskins 1974, 1975; Jones

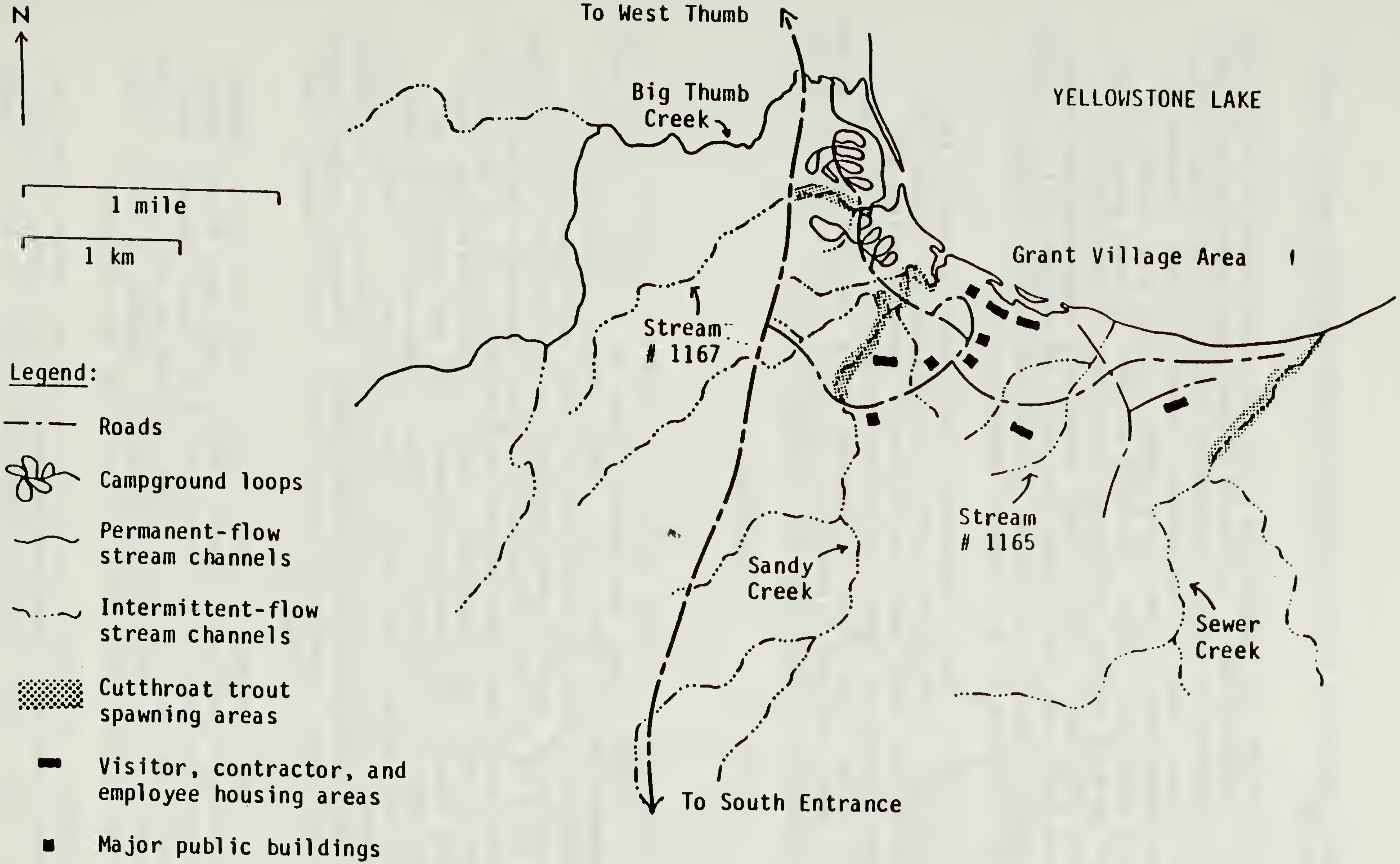


FIGURE 14.-Grant Village area showing major roads, stream channels, buildings, campground loops, housing areas, and cutthroat trout spawning areas.

et al. 1986) revealed that cutthroat trout usually do not spawn in this stream.

Field procedures.-Beginning 1 May in each year of the study, Stream 1167, Sandy Creek, and Sewer Creek were checked daily to detect the presence of adult cutthroat trout. Once adult trout were found (i.e., onset of spawning), weekly visual counts of adult trout were used to estimate peak periods and relative magnitude of spawning runs. In each stream on each sample day, two-to-four people walked upstream from the stream mouth and recorded the number of adult trout observed; observations were made between 1030 and 1800 hours to maximize comparability among streams. Weekly counts continued until most adult trout had returned to the lake (i.e., end of spawning).

While counting fish, observers also recorded bear sign (e.g., sightings, fish parts, scat, and tracks). Tracks and track measurements were used to determine bear species and estimate the number of bears using the streams. Overlapping track sizes (less than 1-cm difference) were considered to be the same bear. Bear use was classified as light, moderate, or heavy based on techniques developed by Reinhart (1988).

Results

1991

Cutthroat trout.-Adult cutthroat trout were first found in Stream 1167, Sandy Creek, and Sewer Creek on 1 June, 2 June, and 6 June, respectively (Figure 15). Peak counts occurred on 12 June in Sandy and Sewer creeks and 26 June in Stream 1167; however, counts of adult trout reached an unusual secondary peak in Stream 1167 on 10 July because flow had become intermittent, and fish in a pool near the bridge at the west end of the lagoon were unable to migrate upstream. The highest single-day count was in Sandy Creek, followed by Stream 1167 and Sewer Creek. Adult trout were last observed in Sewer Creek on 18 July and in Stream 1167 and Sandy Creek on 31 July (Figure 15). Some adult trout were temporarily stranded in pools in Stream 1167 and Sandy Creek when streamflows became intermittent; however, heavy rains in July raised water levels in both streams, and stranded fish were able to return to the lake.

In 1991, peak counts of adult trout in Stream 1167, Sandy Creek, and Sewer Creek were lower than in any year since 1986. The difference was especially pronounced in Sewer Creek, where the peak count dropped from 915 fish in 1990 to 133 fish in 1991. For the first time since the study began, counts of adult trout in Sewer Creek were lower than in the other two streams.

Bears.-Based on track analyses, it was estimated that two grizzly bears (one adult and one subadult) and three or four black bears used Grant Village spawning streams in 1991. Bear

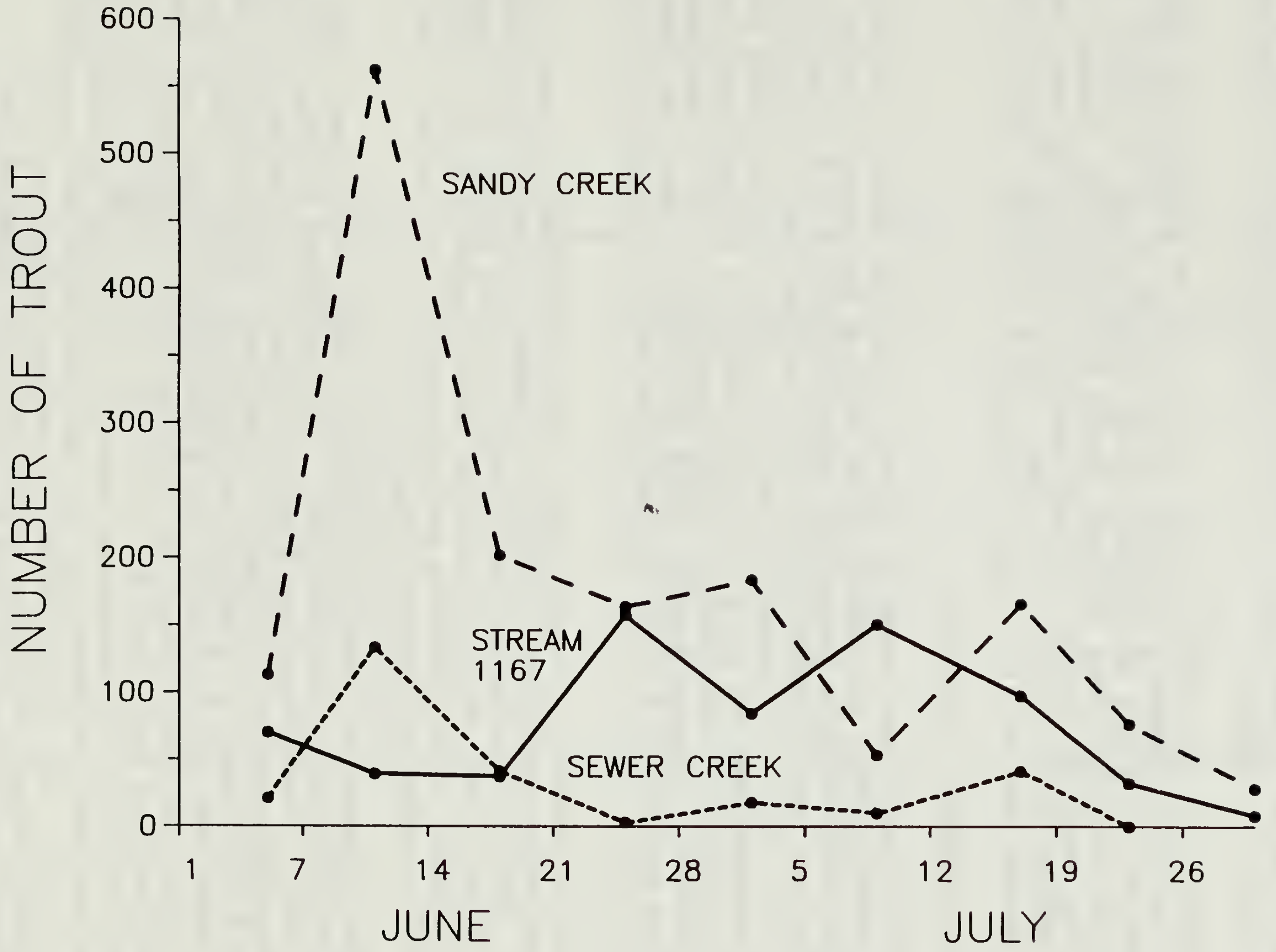


FIGURE 15.-Counts of adult cutthroat trout in three streams in Grant Village, 1991.

sign was most evident on Sewer Creek on 19 June and on Stream 1167 on 3 July. Bear sign on Sandy Creek was most evident (classified as moderate) between 3 and 18 July. Bear sign was last observed on 3 July on Stream 1167 and on 18 July on Sandy and Sewer creeks (Table 6). One grizzly bear was trapped and removed from a stream near Grant Village during the cutthroat trout spawning season.

Human-use management.-The Grant Village Campground opened in stages in 1991: loops E through L opened on 20 June; loops C and D opened on 26 June; and loops A and B opened on 28 June. The Sandy Creek picnic area and the Grant Village boat launch opened on 4 July, and the Grant Village employee fire ring near Sewer Creek opened on 28 July. All other Grant Village "bear-closure" areas opened for visitor use on 31 July.

Six-Year Trends (1986-1991)

Cutthroat trout.-Weekly counts of adult trout in Stream 1167, Sandy Creek, and Sewer Creek during the past 6 years revealed considerable variation among years in the onset and end of cutthroat trout spawning activity in the Grant Village area (Table 7). Onset of spawning ranged from the first week of May to the second week of June. End of spawning ranged from late June to late July and usually occurred when streamflows became intermittent. In most years, some adult trout were stranded in pools and unable to return to the lake when streamflows became intermittent.

Weekly counts of adult trout during the past 6 years also revealed some consistent patterns in spawning activity within years. Spawning activity in Stream 1167 and Sandy Creek usually began about 1 week earlier than in Sewer Creek. In all three of these streams, peak spawning periods usually occurred 1 to 2 weeks after spawning activity began.

Bears.-Based on track-measurement data, which were only collected from 1989 through 1991, the estimated maximum number of bears (i.e., lone bears and family groups) using Grant Village area spawning streams fluctuated from four (three grizzly bears and one black bear) in 1989 to seven (four grizzly bears and three black bears) in 1990 to six (two grizzly bears and four black bears) in 1991. Factors that may have contributed to the observed decline from 1990 to 1991 are that, in 1990, one grizzly bear was trapped and relocated outside the Grant Village area, and one bear was accidentally hit and killed by an automobile. Also, in 1991, the "late" spawning season coincided with increasing visitor activity, which may have reduced the opportunity for non-habituated bears to forage on spawning cutthroat trout.

Observations of bear sign that were made along Grant Village spawning streams during the study revealed that bear activity was

TABLE 6.-Observed bear activity (light, moderate, or heavy) along three Yellowstone Lake tributaries in Grant Village, 1991 (weekly counts of adult cutthroat trout in parentheses).

Date	Stream 1167	Sandy Creek	Sewer Creek
6 June	light (70)	light (113)	none (21)
12 June	none (39)	none (561)	moderate (133)
19 June	none (37)	moderate (201)	heavy (41)
26 June	none (157)	none (163)	moderate (3)
3 July	moderate (84)	moderate (183)	moderate (18)
10 July	none (150)	moderate (53)	moderate (10)
18 July	none (97)	moderate (165)	moderate (41)
24 July	none (32)	none (76)	none (0)
31 July	none (8)	none (28)	not checked

usually greatest 1 to 4 weeks after peak spawning periods. In a few instances, however, greatest bear activity coincided with peak spawning, and in two cases, greatest bear activity occurred from 1 week before until 1 week after peak spawning.

TABLE 7.-Estimated timing of cutthroat trout spawning activity in the Grant Village area, 1986-1991.

Year	Onset	Peak	End	Maximum duration (weeks)
1986	early June	early-to-mid June	late July	8
1987	early May	mid-to-late May	late June	8
1988	mid-May	late May to early June	late June	5
1989	mid-May	late May to early June	late June	7
1990	mid-May	late May	mid-July	10
1991	early June	mid-to-late June	late July	9

Discussion

Cutthroat Trout

Timing of cutthroat trout spawning runs in Grant Village area streams, as in other Yellowstone Lake tributaries, appeared to be influenced by several environmental factors. Spawning usually began as high spring flows subsided, water clarity increased, and water temperatures rose above 8°C. Factors affecting time of peak spawning in Grant Village area streams are poorly understood, but spawning-run duration appeared largely influenced by intermittent streamflow. Magnitude of spawning runs in these streams is probably a function of available spawning habitat.

Bears

Reinhart (1990) stated that the track-measurement method probably underestimated the number of bears using a spawning stream; thus, it is possible that the number of bears using Grant Village area spawning streams from 1989 through 1991 was greater than reported. Substrate suitable for identifying tracks was not always present. Also, French and French (1990) observed that bears preying on fish often walked in the stream, thus reducing the presence of tracks.

Reinhart and Mattson (1987) found that the amount of bear activity along Yellowstone Lake tributaries during the cutthroat trout spawning season usually began during peak spawning periods, was greatest just after peak spawning, and declined thereafter. During years when spawning activity is relatively "late" (i.e., when spawning begins in late May or early June and extends into July), this relationship may, even with the current restrictions on human use, increase the potential for human-bear conflicts. In 1991, for example, a lone adult grizzly bear was active along Stream 1167 and Sandy Creek until late July, long after the Grant Village campground and other facilities in the Grant Village area were open to visitors. Also, in years when adult trout become stranded in pools under intermittent flow conditions, bears may be active along the streams for longer periods than would be expected under permanent flow conditions.

Reinhart and Mattson (1990) found that bear activity along Yellowstone Lake cutthroat trout spawning streams within 1 km of park developments was less than expected despite sometimes high spawner densities. Bears that use spawning streams near developments, however, may become habituated to humans. Habituation may result when the attraction to "natural" foods (e.g., spawning cutthroat trout) outweighs the tendency of bears to avoid humans, or when subdominant bears are displaced by dominant bears into areas of high human use. Adult female and subadult grizzly bears are more likely than other grizzly bears to forage closer to developments and become habituated (Mattson et al. 1987); consequently, these animals are more likely to be involved in management actions such as trapping and relocation (Mattson 1990).

Management Actions and Recommendations

Management actions used by the NPS in the Grant Village area during the cutthroat trout spawning season include: 1) monitoring trout spawning and associated bear activity; 2) phasing in visitor use at the Grant Village campground and boat launch and the Sandy Creek picnic area; 3) educating visitors with a slide show at the Grant Village amphitheater; 4) restricting human access to areas near spawning streams; and 5) trapping and relocating bears. These management actions should be reviewed and updated annually.

The current low-cost monitoring technique provides information that is useful for reducing the potential for human-bear conflicts in the Grant Village area during the cutthroat trout spawning season. It is recommended that monitoring of cutthroat trout spawning and bear activity be continued in 1992.

YELLOWSTONE RIVER:
YELLOWSTONE LAKE OUTLET TO UPPER FALLS

Fishing for Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls has been popular since Jordan (1891) and Everman (1892) reported that trout in this reach were abundant. Currently, this section of river is the second-most-popular fishery in Yellowstone National Park. It also may be one of the most intensively fished wild trout fisheries in North America (Jones et al. 1990).

Increasingly restrictive angling regulations have been implemented over the years to protect the native cutthroat trout population in this section of the Yellowstone River. The daily limit was 20 trout during the 1920s, 10 trout during the 1930s, and five trout between 1949 and 1953 (Dean and Mills 1971). The daily limit was reduced to three trout in 1953 (Dean and Mills 1971), despite the conclusion of Moore et al. (1952) that angling was not negatively affecting the population. Subsequently, Benson and Bulkley (1963) concluded that the population was being overexploited by anglers, recommended that the daily limit be reduced, and requested that a minimum-length limit be established. However, no further changes in angling regulations were made until 1973, when catch-and-release-only angling was instituted.

The fishing season has been shortened over the years to increase protection of the trout population during the spawning season. Before 1938, the season opened on 23 May; between 1938 and 1964, the season opened on 1 July; since 1965, the season has opened on 15 July (Dean and Mills 1971). In most years, the fishing season closed in late October or early November, and currently the season ends on the first Sunday in November. Although all 26 km of the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls were historically open to angling, the LeHardy Rapids area has been closed since 1949, a 10-km section in Hayden Valley has been closed since 1965, and the section from the Yellowstone Lake outlet to 1.6 km downstream from Fishing Bridge has been closed since 1973.

The goal of this report is to present results from studies conducted in 1991 and evaluate long-term trends in the sport fishery and Yellowstone cutthroat trout population of the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls.

Study Areas

Catch-and-Release Areas

Two sections of the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls are currently open to angling. The upper section, nearly 10 km long, begins about 1.6 km below Fishing Bridge and extends downstream to Sulphur Caldron. The lower section starts at the confluence of Alum Creek and the Yellowstone River and extends downstream for 5 km to Chittenden Bridge (Figure 16).

LeHardy Rapids

LeHardy Rapids, a series of small cascades 6 km downstream from the Yellowstone Lake outlet, is within the boundaries of the upper catch-and-release area (Figure 16). During spawning season (May through July), cutthroat trout congregate in pools on the west bank of the river immediately below the rapids. A boardwalk and viewing platform allow visitors to watch trout ascend the rapids.

Methods

Data sources and field procedures.-Manned creel surveys and the Volunteer Angler Report (VAR) system provide information on the cutthroat trout sport fishery. Manned creel survey results have been converted from "summer" to "season-long" estimates and averaged for the periods 1951 through 1955, 1967 through 1968, and 1970 through 1972 to maximize comparability with season-long VAR estimates for the years 1973 through 1991. Estimates of sport-fishery parameters reported for 1991 include the number of anglers, angler use (number of fishing trips), angler effort (number of hours fished), number of trout landed, mean landing rate (average number of trout landed per hour), mean length of landed trout, number of trout illegally harvested, percentage of anglers satisfied with their fishing experience, and mean expertise level of anglers. Long-term analyses, however, are restricted to angler effort, mean-annual landing rate, and length structure of trout landed (mean length, Proportional Stock Density estimates, and Relative Stock Density estimates).

The LeHardy Rapids study provides information on the cutthroat trout spawning population. Since 1974, cutthroat trout spawners have been sampled weekly throughout the spawning season. On each sample day, a maximum of 100 trout are collected by dipnet from pools along the west bank of the river just downstream from the rapids. Captured trout are classified by sex and spawning condition, measured to the nearest 1 mm total length, and weighed to the nearest 2 g. Scales are collected from a subsample of captured trout for age-growth analysis. Ages are estimated by the scale method (Bagenal and Tesch 1978), and results are expanded with an age-length key (Westrheim and

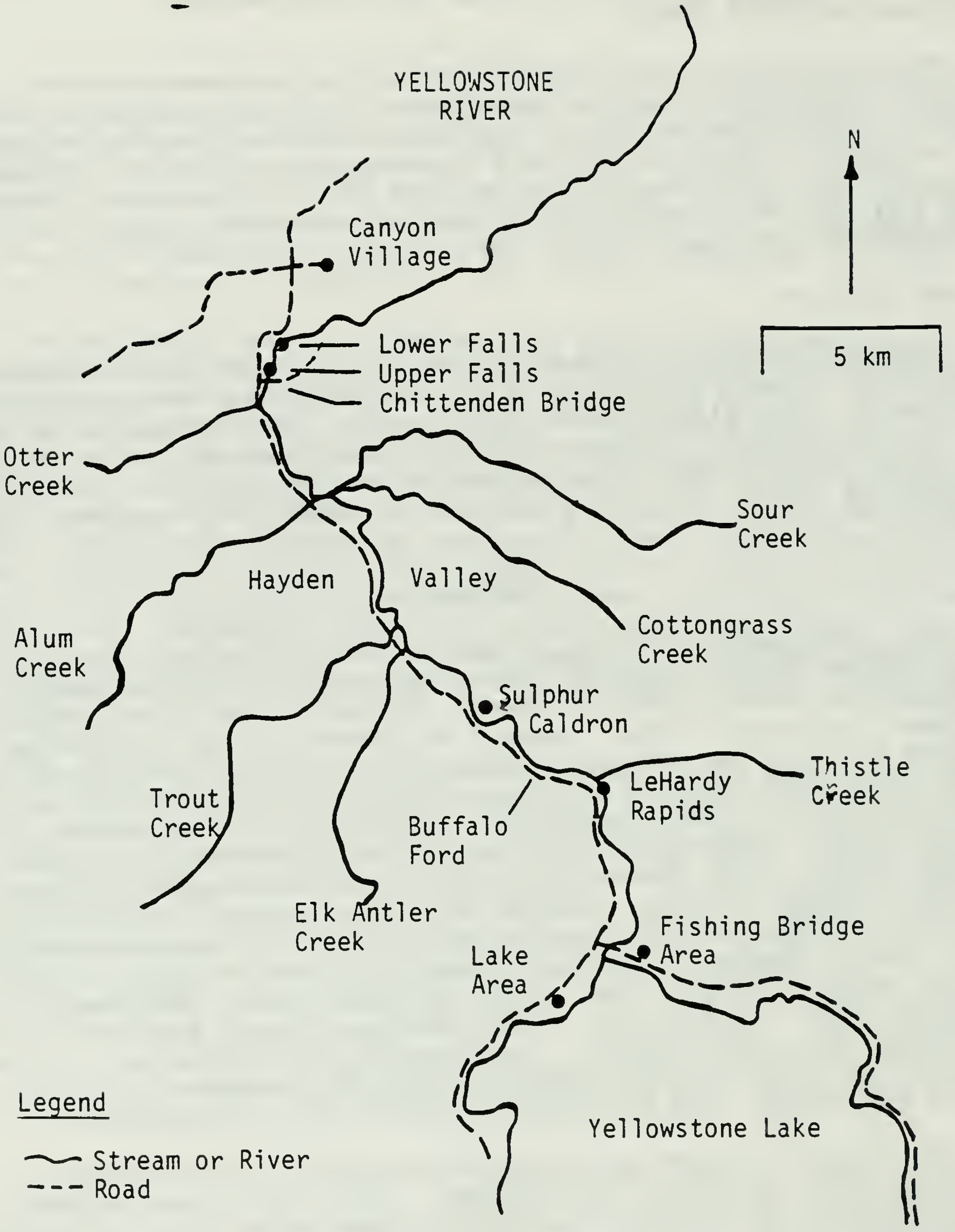


FIGURE 16.-Yellowstone River, Yellowstone National Park, from Yellowstone Lake outlet to the Upper Falls.

Ricker 1978) to obtain an estimate of mean age. In 1991, cutthroat trout were sampled at LeHardy Rapids for 9 consecutive weeks between late May and late July. Long-term analyses of data obtained from the LeHardy Rapids study are restricted to length structure and mean age.

Length-structure analysis.-Proportional Stock Density (PSD) and Relative Stock Density (RSD) are length-frequency indices (Gabelhouse 1984) that eliminate the influence of smaller fish in data analysis. "Stock," "quality," and "preferred" lengths for cutthroat trout in this study were set at 254, 356, and 406 mm, respectively. Although a preferred length of 406 mm is less than that recommended by Gabelhouse (1984), the relatively low growth potential of cutthroat trout in the Yellowstone River was an overriding consideration.

Results

Current Year

Sport fishery.-In 1991, an estimated 19,000 anglers made 52,000 fishing trips and spent 144,000 h fishing the catch-and-release-only sections of the Yellowstone River. In these two sections, anglers landed just over 121,000 Yellowstone cutthroat trout. Average landing rate was 0.8 trout/h, and mean length of landed fish was 407 mm. An estimated 36 trout were illegally creeled. Nearly 84% of the anglers were satisfied with their overall fishing experience; 75% were satisfied with numbers of trout landed; 87% were satisfied with sizes of trout landed. About 68% of single-day anglers landed one or more trout. Average angler expertise was 2.0, suggesting that most people who fished these two areas rated themselves as experienced anglers.

LeHardy Rapids.-In 1991, 634 adult cutthroat trout were collected. Mean total length, weight, and condition (K) of these fish were 402 mm, 539 g, and 0.82 (Table 8). Mean total length of males (412 mm) was significantly (t-test; $P < 0.05$) greater than that of females (393 mm). Scale samples were obtained in 1991; however, no age-growth analyses were completed.

Long-term trends

Sport fishery (1950s to 1991).-From the 1950s through 1972, annual angler effort averaged 88,000 h, but in 1973 and 1974 (the first 2 years of the catch-and-release-only regulation), effort dropped to about 57,000 h. Since 1974, however, annual angler effort has risen and averaged 127,000 h over the past 5 years (Figure 17).

Relatively low mean-annual landing rates of about 0.7 trout/h were recorded between the late 1960s and 1972. Mean-annual landing rate rose sharply after implementation of catch-and-release-only angling to a record high of 2.3 trout/h in

TABLE 8.-Mean length, weight, and condition of Yellowstone cutthroat trout captured by dip net at LeHardy Rapids, Yellowstone River, 1974 to 1991.

	Adult males				Adult females				All adults			
Year	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor
1974[a]	177	375	394	0.75	244	352	339	0.78	453	362	363	0.76
1975	338	385	451	0.78	426	359	363	0.78	775	370	401	0.78
1976[a]	531	384	431	0.75	423	362	360	0.75	964	375	399	0.75
1977[a]	133	382	429	0.77	111	362	370	0.78	245	373	402	0.77
1978	399	386	458	0.78	358	364	413	0.85	759	376	437	0.81
1979	334	394	514	0.83	237	371	431	0.84	571	385	480	0.83
1980	293	391	488	0.81	190	372	418	0.80	483	384	460	0.81
1981	383	394	496	0.80	188	373	440	0.84	571	387	478	0.82
1982	327	401	517	0.80	367	380	474	0.86	694	389	494	0.83
1983	338	402	546	0.83	232	380	276	0.86	570	394	517	0.84
1984[b]	321	408	539	0.79	199	386	477	0.82	526	399	515	0.80
1985[b]	269	408	554	0.82	161	391	513	0.85	431	402	539	0.83
1986[b]	279	405	565	0.84	316	388	503	0.85	596	396	532	0.85
1987	21	407	586	0.84	12	389	520	0.88	33	400	562	0.86
1988[a]	60	400	559	0.88	46	385	508	0.88	106	394	537	0.88
1989	186	411	578	0.83	199	387	495	0.85	386	398	535	0.84
1990	223	407	582	0.86	188	385	502	0.88	411	397	546	0.87
1991	326	412	572	0.81	308	393	504	0.83	634	402	539	0.82

[a] Due to erroneous measurements, fish were deleted from average weight and K factor calculations only, as follows: six males and two females from 1974, one male and two females from 1976, one male and one female from 1977, and one male from 1988.

[b] Six adults in 1984, one adult in 1985, one adult in 1986, and one adult in 1989 were not identified to sex.

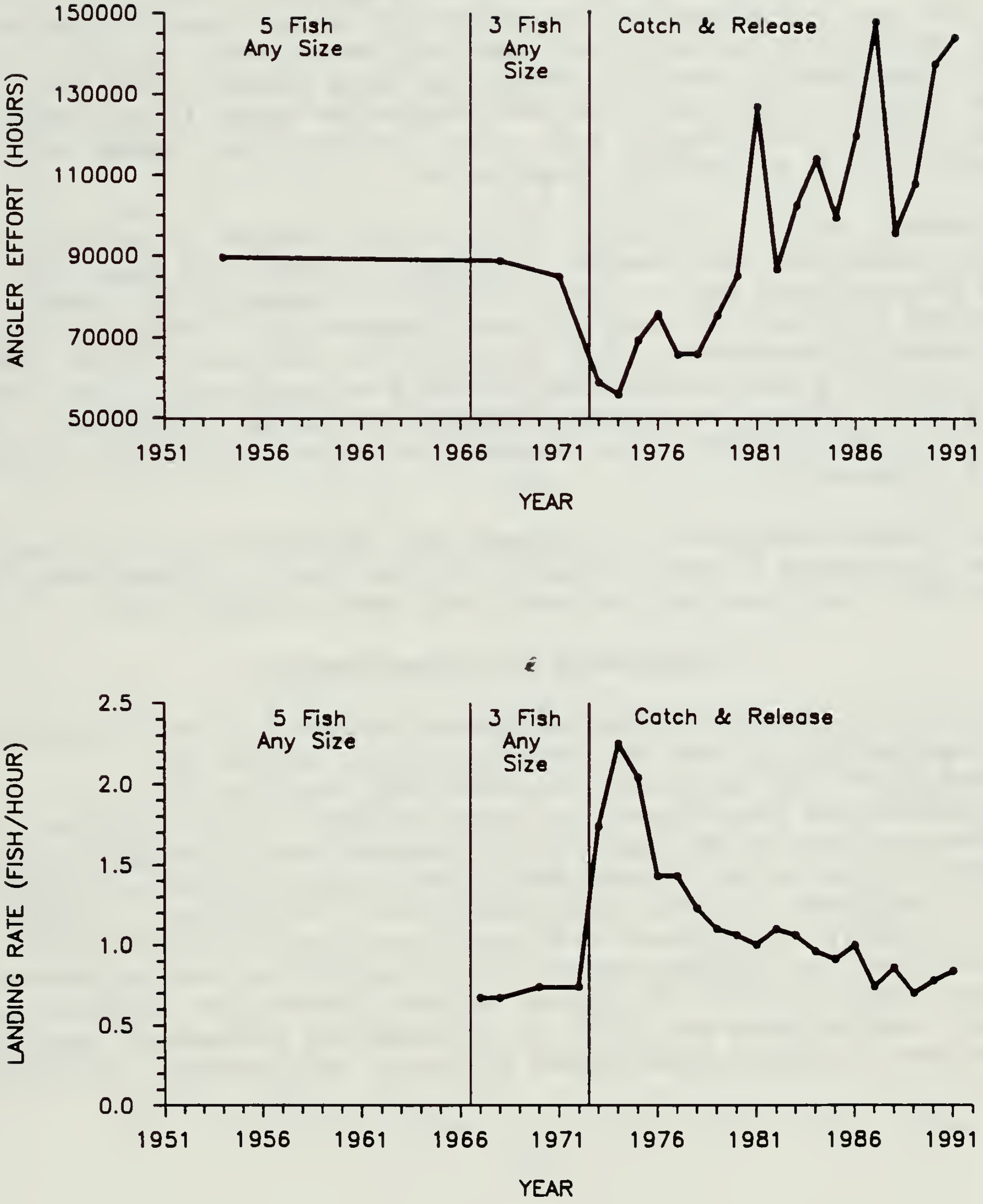


FIGURE 17.-Angler effort (1954 to 1991) and mean-annual landing rate (1967 to 1991) in the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls.

1974 but dropped to 1.2 trout/h by 1978. Since 1978, mean-annual landing rate has continued to decline and has averaged about 0.8 trout/h over the past 5 years (Figure 17).

Mean length of landed trout was smallest (330 mm) in the 1950s but has increased almost annually since then. Largest mean length of angler-landed trout was 412 mm in 1990 (Figure 18). Proportional Stock Density estimates have ranged from 62% in 1975 to 89% in 1990 and 1991, and RSD estimates have fluctuated between 16% in 1975 and 57% in 1990; increasing trends are evident in both estimates (Figure 18).

LeHardy Rapids (1974 to 1991).-Mean length of cutthroat spawners captured was lowest (362 mm) in 1974 and rose to a record high of 402 mm in 1985 and 1991. Since 1985, mean length has varied between 394 and 402 mm (Figure 19). Proportional Stock Density estimates rose from 51% in 1974 to 97% in 1985, and since then have been relatively stable at between 95 and 97% (Figure 19). Relative Stock Density estimates increased from 8% in 1974 to 38% in 1984, and since then have fluctuated between 25 and 41% (Figure 19).

Youngest mean age (3.7 years) was observed in 1974 and 1975 and has increased almost annually since then. Oldest mean age (6.1 years) was observed in 1986 and 1989 (Figure 19).

Discussion and Conclusions

It is evident that changes have occurred in the cutthroat trout population of the Yellowstone River since the implementation of catch-and-release-only angling in 1973. Length-structure data from the sport fishery and length-structure and mean-age data from the LeHardy Rapids study revealed that the relative abundance of larger and older trout increased almost annually between 1974 and the mid-1980s. Relatively little change in length structure and mean age since the mid-1980s suggests that the population may be stabilizing under current management practices. If angler effort increases substantially, however, regulations may need to be amended to ensure compliance with current fishery management goals in Yellowstone National Park.

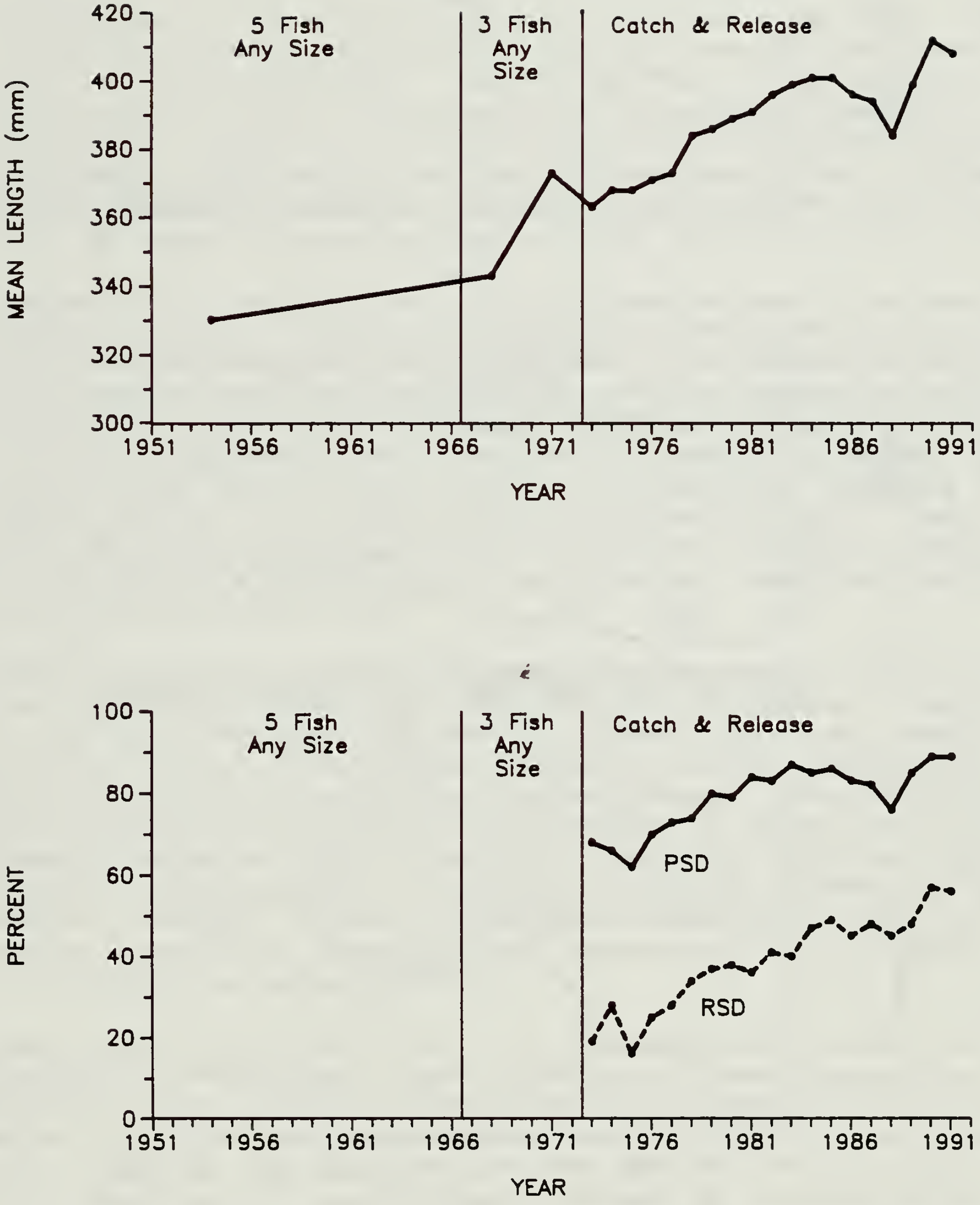


FIGURE 18.-Mean length (1954 to 1991) and length structure (1973 to 1991) of angler-landed cutthroat trout from the Yellowstone River between the Yellowstone Lake outlet and the Upper Falls.

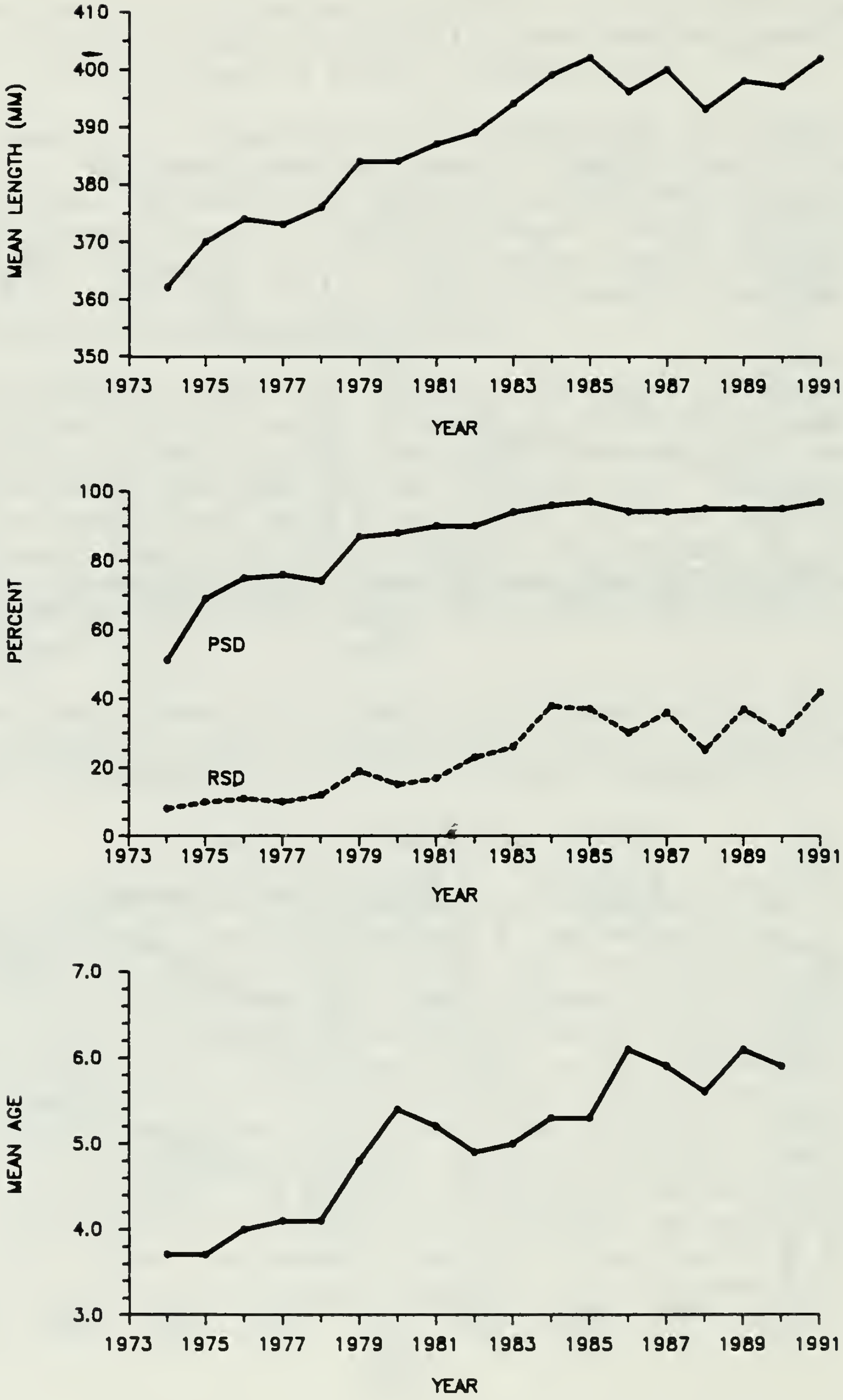


FIGURE 19.-Mean length, length structure, and mean age of cutthroat trout captured by dipnetting at LeHardy Rapids, 1974 to 1991 (no age data for 1991).

REPRODUCTIVE ECOLOGY OF CUTTHROAT TROUT IN THE YELLOWSTONE RIVER AND POTENTIAL EFFECTS OF WADING BY ANGLERS ON TROUT FRY EMERGENCE

Yellowstone Lake and the Yellowstone River upstream from the Upper Falls have large populations of Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* (Behnke 1979). The fish are important food for avian and mammalian predators (Davenport 1974; Reinhart 1990). Angling for cutthroat trout has been popular since the late 1800s and today the Yellowstone River is the second-most-popular fishery in Yellowstone National Park (Table 3).

Increasingly restrictive angling regulations have been implemented over the years to protect the cutthroat trout, manage the river as part of the park ecosystem, provide for fish and wildlife viewing, and provide quality angling opportunities. Three sections of the river between Yellowstone Lake and the Upper Falls, totaling 12 km, have been closed to angling since at least 1973: from Yellowstone Lake to 0.6 km below Fishing Bridge, the LeHardy Rapids area, and 10 km in Hayden Valley. The remaining 14 km of the Yellowstone River are open to fishing from 15 July through the first Sunday in November; angling has been catch-and-release since 1973.

Recently there has been concern that wading by anglers on redds may increase mortality of developing cutthroat trout embryos and pre-emergent fry. In a laboratory study, wading killed up to 83% of Yellowstone cutthroat trout embryos and pre-emergent fry in simulated gravel redds; amount of mortality depended on wading frequency and the stage of embryo or fry development (Roberts 1988). In 1990, the U.S. Fish and Wildlife Service and Montana State University initiated a study of the reproductive ecology of the Yellowstone cutthroat trout in the Yellowstone River and the potential effects of angler wading on trout fry emergence success.

Study objectives were to: (1) document the timing and distribution of cutthroat trout spawning; (2) document the timing of cutthroat trout embryonic developmental stages, hatching, and emergence; (3) monitor the distribution, abundance, and growth of cutthroat trout fry; (4) document the amount and distribution of wading by anglers; (5) estimate the amount of pre-emergent mortality due to angler wading; (6) examine movements of adult cutthroat trout; and (7) evaluate the potential of tributary streams for cutthroat trout reproduction and recruitment in the Yellowstone River.

Study Area

The Yellowstone River originates in the Bridger Teton Wilderness Area in northwest Wyoming and flows northwesterly to

Yellowstone Lake. The lake, which has a surface area of 354 km^2, drains into the lower Yellowstone River at its northern end. Mean flow (USGS 1927-1990) of the Yellowstone River is 37.64 m^3/s at the gaging station 0.6 km downstream from the lake outlet. The study was conducted on the Yellowstone River between the outlet of Yellowstone Lake and Upper Falls, 26 km downstream, and on seven tributaries in this river reach (Figure 16).

The Yellowstone River drops from an elevation of 2,357 m to 2,326 m between Yellowstone Lake and Upper Falls and has an average gradient of 1.2 m/km. The river is predominantly meandering and generally stable, except between LeHardy Rapids and Sulphur Caldron where geologic faults create river rapids. Aquatic vegetation covers much of the river bottom during summer and the channel has numerous gravel bars.

The study area was divided into three segments on the basis of differences in channel morphology. The upper segment extends 6 km downstream from the Yellowstone Lake outlet to LeHardy Rapids; the middle segment includes the next 5 km of river to Sulphur Caldron; and the 15-km lower segment is between Sulphur Caldron and the Upper Falls. The upper segment is deep and slow-moving, whereas the middle segment flows rapidly and carries coarser sediments, much of which is deposited in the Buffalo Ford area (Skinner 1977). The upper and middle river reaches are in lodgepole pine *Pinus contorta* forest. The low-gradient lower segment meanders through the Hayden Valley, a broad sage grassland, where it is joined by Elk Antler, Trout, Alum, Cottongrass, and Sour creeks. Just below Alum Creek, the river again enters a lodgepole pine forest, where it flows for about 5 km before plunging over the 33-m Upper Falls, a barrier to upstream fish movement. For data collection, the river was further divided into 87 study sections separated by obvious landmarks or marked differences in river substrate.

In addition to the native Yellowstone cutthroat trout, small populations of native longnose dace *Rhinichthys cataractae* and the introduced redside shiner *Richardsonius balteatus* and longnose sucker *Catastomus catastomus* occur in the Yellowstone River.

Methods

Water quality and river discharge.-Water chemistry parameters were measured periodically in each of the three river segments and the tributaries. Dissolved oxygen was measured with a Hach OX-2P field kit and alkalinity with a Hach AL-AP field kit. A Hellige color comparator was used to estimate pH, and conductivity was determined with a Beckman Solu-bridge meter (Model Rb-5). One water sample from each of the three river segments, collected in late June or early July, was analyzed by a commercial laboratory.

Ryan Tempmentors recorded water temperatures in each of the three study segments at 1-h intervals from mid-May to mid-September, and a hand-held thermometer was used to periodically measure temperatures elsewhere. Discharge was measured at a U.S. Geological Survey station, 0.6 km downstream from the Yellowstone Lake outlet.

Cutthroat trout spawning habitat.-River substratum was mapped from Yellowstone Lake to Chittenden Bridge by visually estimating the particle size composition to the nearest 25%, using a modified Wentworth scale (Welch 1948; Table 9). Observations were made from a rowboat or the river bank in May and September, when visibility was good and water levels were low.

TABLE 9.-Substrate size classification modified from the Wentworth particle size scale.

Substrate class	Particle size range (mm)
Fines	<2.0
Gravel	2.0 - 64.0
Cobble	64.0 - 250.0
Boulder	>250.0

Substrate samples for particle analysis were collected from 10 redds in each of the three study segments. A shovel blade (34 cm wide, 38 cm long) was driven vertically into the substrate to a depth of 25-30 cm, turned horizontally, and lifted from the water. Water depth, to the nearest centimeter, and velocity, at 0.6 depth, were measured at the upstream margin of the tailspill of each of the 30 redds sampled.

Spawning activity and redd distribution.-Adult trout and redds were counted weekly between 10 June and 12 July by visual observation from a rowboat, river banks, or hillsides. Each week the numbers of trout and redds were recorded for both the east and west river banks.

Embryonic development.-To monitor embryonic development, eggs collected and artificially fertilized on 5 and 20 June and 12 July at LeHardy Rapids were incubated in Astroturf substrate in two modified Porter (1973) boxes placed in the side channel at Buffalo Ford. A Ryan Tempmentor placed nearby recorded temperatures and allowed calculation of centigrade temperature units (CTU; sum of mean-daily temperatures above 0°C). Embryos and pre-emergent fry developing in the Porter boxes and natural redds were examined periodically to assess development stage as uneyed, eyed, or hatched.

Cutthroat trout fry.-To document the time of emergence, fry were visually counted in nine (three in each river segment) 25-m longitudinal transects along the west river bank. Counts were made on 18 d between 23 July and 5 September.

The east side of the river was floated weekly between 25 July and 21 August to monitor fry distribution. Fry were visually counted and their abundance rated (Table 10) along 15, 25-m longitudinal transects between Fishing Bridge and LeHardy Rapids and along various similar transects below LeHardy Rapids. Fry abundance was estimated for all 87 sections.

TABLE 10.-Cutthroat trout fry-abundance ratings and estimated numbers of fry per 25 m of shoreline.

Fry abundance rating	Estimated number of fry per 25 m
None	0
Rare	1 - 4
Few	5 - 19
Common	20 - 49
Abundant	50 - 99
Very Abundant	>100

Between 26 July and 5 September, over 1,300 fry were dipnetted from slow water along the east and west banks of the river and measured to the nearest millimeter total length to assess growth of fry.

Wading by anglers.-Because the amount of embryo and pre-emergent fry mortality depends in part on the frequency of wading by anglers, locations and numbers of anglers were surveyed on 37 d between 15 July and 30 August; during this 7-week period, surveys were conducted on all weekdays and the weekend days of July 20 and 21 (opening weekend of the fishing season). For each census, the surveyor observed all 43 sections open to fishing and counted wading and non-wading anglers along the east and west banks.

Tributaries.-The lower reaches of Thistle, Trout, Elk Antler, Sour, Alum, and Otter creeks were surveyed at least four times each to evaluate their potential for cutthroat trout reproduction and recruitment to the Yellowstone River. Dominant substratum and the presence and abundance of redds, adult, juvenile, and young-of-the-year cutthroat trout were evaluated.

Trout fry were counted along 25-m transects and fry were dipnetted and measured to the nearest millimeter total length. For each tributary, one water sample was collected and extensively analyzed commercially, and routine water chemistry parameters were measured twice in the field. Temperatures were measured periodically with a hand-held thermometer.

Movements of adult trout.-To document trout movement patterns, 1,478 trout were tagged with colored and numbered Floy tags in May and June 1990. Tag colors were specific to each of the three river segments. In 1991, tag-return information was acquired from anglers, weekly dipnet sampling at LeHardy Rapids (see report on Yellowstone River, this volume), and visual observations made while floating the river.

Preliminary Results

Water quality and river discharge

Chemical characteristics of the Yellowstone River (Table 11) were within the range suitable for cutthroat trout (Hickman and Raleigh 1982; Alabaster and Lloyd 1982; USEPA 1986). Between 7 May and 15 September, water temperature ranged from 0.3°C in early May to 19.1°C on 3 August (Table 12). River discharge for May through September ranged between 18.1 m^3/s and 160.6 m^3/s (Table 13).

Spawning activity and redd distribution

Spawning of cutthroat trout began in late May, peaked between late June and early July, and was mostly complete by mid-to-late July. Cutthroat trout spawned in all three study segments but redd density varied from none to an estimated 280 redds per river section.

Embryonic development

Eggs artificially spawned on 5 June were eyed by 28 June, and eggs from 20 June were eyed by 16 July. On 11 and 12 July, uneyed and eyed eggs were collected from redds in the upper and middle river segments. On 16 July, eggs artificially spawned on 5 June were hatched, eggs from 20 June were eyed, and eggs from 16 July were uneyed. Several natural redds in each of the three study segments were checked on 25 July and pre-emergent fry were found in each segment.

Cutthroat trout fry

Cutthroat trout fry were first observed during shoreline surveys on 22 July near the Otter Creek outlet, but few fry were seen in the upper and middle segments before 29 July. Abundance of cutthroat fry peaked between 2 amd 13 August (Figure 20).

TABLE 11.-Chemical characteristics of the middle and lower study segment of the Yellowstone River (YSR), Thistle and Elk Antler creeks, 1991. Turbidity expressed in NTU's, color in PCU's, other values (except pH, stability index, and saturation index) expressed in mg/L.

	Middle YSR	Lower YSR	Thistle Creek	Elk Antler Creek
Date (1991)	06-28	07-02	07-01	07-02
Total Dissolved Solids	46.0	78.0	72.0	190
Phenolphtalein Alk.	<2.0	<2.0	<2.0	<2.0
Total Alkalinity	26.4	34.5	26.4	57.8
Carbonate Alkalinity	<2.0	<2.0	<2.0	<2.0
Bicarbonate as CaCO3	26.4	34.5	26.4	57.8
Carbonates	<2.0	<2.0	<2.0	<2.0
Bicarbonates as HCO3	26.4	34.5	26.4	57.8
Hydroxides	<0.50	<0.50	<0.50	<0.50
Carbon Dioxide	<1.0	2.80	2.2	1.7
Chloride	2.98	6.95	<1.0	14.9
Sulfate	4.96	10.2	2.24	24.8
Flouride	0.41	0.77	1.14	3.10
pH (Laboratory)	8.01	7.38	7.35	7.82
Stability Index	10.5	10.8	15.7	9.16
Saturation Index	-1.23	-1.70	-4.15	-0.67
Color (estimated)	<5	5	10	20
Turbidity	1.66	2.30	0.56	3.00
Silica	11.1	16.8	37.3	61.2
Hydrogen Sulfide	<0.10	<0.10	<0.10	<0.10
Sodium	7.30	14.0	4.80	25.0
Potassium	1.40	3.10	2.40	6.40
Calcium	5.20	6.20	7.20	16.0
Magnesium	1.90	2.70	2.00	5.70
Iron	0.56	0.17	0.12	0.38
Manganese	<0.03	<0.03	<0.03	0.09
Copper	<0.01	<0.01	<0.01	<0.01
Total Hardness	21.0	27.0	26.0	65.0
Magnesium Hardness	7.90	11.0	8.30	24.0
Calcium Hardness	13.0	16.0	18.0	41.0

TABLE 12.-Monthly temperature range, Yellowstone River, May 3 - September 16, 1991.

Month	Temperature Range (°C)
May	0.3 - 7.8
June	0.8 - 10.5
July	5.8 - 17.3
August	13.0 - 19.1
September	0.7 - 18.6

TABLE 13.-Monthly mean, minimum, and maximum flows, Yellowstone River 0.5 km downstream of Yellowstone Lake outlet, May - September, 1991.

Month	Mean flow (m^3/s)	Minimum flow (m^3/s)	Maximum flow (m^3/s)
May	37.18	18.10	78.45
June	136.90	80.15	160.57
July	109.37	76.75	143.58
August	56.27	40.78	75.90
September	31.75	25.40	39.93

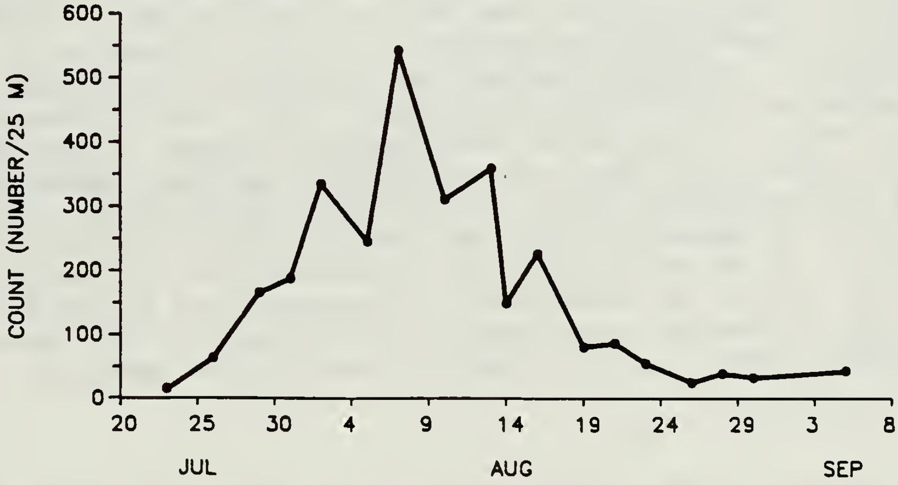


FIGURE 20.-Fry counts on the Yellowstone River, 1991.

Between 26 July and 5 September, average size of fry in dipnet samples increased from less than 25 mm to more than 36 mm, and percentage of recently hatched fry ($\leq$ 25 mm) decreased from 85% to less than 3% (Table 14). Cutthroat trout fry were found throughout the river but abundance varied from none to very abundant among sampling sites.

Wading by anglers

Based on Volunteer Angler Report (VAR) data, anglers fished an estimated 144,000 h in the study area in 1991. Ninety-five percent of this effort occurred between Fishing Bridge and Sulphur Cauldron (Table 15). Most anglers fished along the west bank of the river, which is easily accessed from the road. The east bank is reached by hiking the Howard Eaton Trail or wading across the river. River crossing is limited primarily to Buffalo Ford and in 1991 few anglers crossed before early August because of high flows.

Tributaries

Although each of the tributaries contained substratum that appeared suitable for spawning, evidence of spawning was found only in Thistle, Elk Antler, and Trout creeks where all life stages of cutthroat trout were observed. Chemical analyses of Thistle, Elk Antler, and Trout Creek waters revealed no major water quality problems for cutthroat trout (Table 16).

Trout were not observed in Alum, Sour, and Otter creeks. Numerous longnose dace and redside shiner inhabit the middle and lower reaches of Alum Creek, but water temperatures exceed 22°C, the maximum suitable temperature for cutthroat trout (Hickman and Raleigh 1982). The maximum temperature recorded in the lower reach of Alum Creek in 1991 was 23°C at 1445 h on 21 June. Jones et al. (1983) reported a temperature in Alum Creek of 27.8°C in late July 1982. Water collected on 1 July in Sour Creek had a pH of 3.39, alkalinity <2.0 mg/L as $CaCO_3$, and iron concentration of 1.70 mg/L. Otter Creek water sampled on 25 June had a pH of 4.38 and an alkalinity <2.0 mg/L as $CaCO_3$ (Table 16). Water quality criteria for freshwater aquatic life are: pH between 6.5 and 9; alkalinity of at least 20 mg/L as $CaCO_3$; iron less than 1.0 mg/L (USEPA 1986). A pH below 6.5 may be harmful to salmonids and pH below 4.0 is lethal to salmonids (Alabaster and Lloyd 1982). Also, low pH increases iron toxicity. At pH 5.5 the 96-h LC50 of iron for brook trout was 0.41 mg/L (Decker and Menendez 1974).

Movements of adult trout

There were 91 tag returns or observations of tagged fish in 1990 and 1991, but no definitve movement patterns were evident among these fish (Table 17).

TABLE 14.-Weekly mean total length of cutthroat trout fry and percent of fry ≤25 mm total length, July 26 - September 5, 1991.

Week	N	Average length (mm)	N<25 mm	% <25mm
7/26	20	24.2	17	85
7/29 - 8/2	160	25.6	81	51
8/5 - 8/9	307	25.8	163	53
8/12 - 8/16	330	27.1	141	43
8/19 - 8/23	206	30.9	30	15
8/26 - 8/30	212	31.9	24	11
9/2 - 9/5	72	36.8	2	3

TABLE 15.-Fishery statistics for the Yellowstone River from Volunteer Angler Report (VAR) system, 1991.

Area	Angler days (trips)	Angler hours (effort)
Fishing Bridge - Sulphur Caldron	48,725	136,766
Alum Creek - Chittenden Bridge	3,449	7,198

TABLE 16.-Chemical characteristics of Trout, Sour, Alum, and Otter creeks, 1991. Turbidity expressed in NTU's, color in PCU's, other values (except pH, stability index and saturation index) expressed in mg/L.

	Trout Creek	Sour Creek	Alum Creek	Otter Creek
Date (1991)	07-02	07-01	07-02	06-25
Total Dissolved Solids	160	192	708	126
Phenolphtalein Alk.	<2.0	<2.0	<2.0	<2.0
Total Alkalinity	30.4	<2.0	184	<2.0
Carbonate Alkalinity	<2.0	<2.0	<2.0	<2.0
Bicarbonate as CaCO3	30.4	<2.0	184	<2.0
Carbonates	<2.0	<2.0	<2.0	<2.0
Bicarbonates as HCO3	30.4	<2.0	184	<2.0
Hydroxides	<0.50	<0.50	<0.50	<0.50
Carbon Dioxide	7.3	*	1.80	*
Chloride	3.97	4.96	101	12.9
Sulfate	40.9	82.7	96.3	30.9
Flouride	2.87	0.67	8.41	1.17
pH (Laboratory)	6.91	3.39	8.28	4.38
Stability Index	10.9	18.1	7.76	17.2
Saturation Index	-1.98	-7.37	0.26	-6.42
Color (estimated)	40	20	10	50
Turbidity	5.90	2.20	1.34	1.48
Silica	52.8	61.0	146	40.4
Hydrogen Sulfide	<0.10	<0.10	<0.10	<0.10
Sodium	17.0	17.0	160.0	15.0
Potassium	4.90	6.60	33.0	4.40
Calcium	12.0	5.30	17.0	4.50
Magnesium	4.40	1.20	3.90	<1.00
Iron	1.10	1.70	0.38	0.48
Manganese	0.06	0.06	0.04	0.08
Copper	<0.01	<0.01	<0.01	<0.01
Total Hardness	48.0	18.0	58.0	11.0
Magnesium Hardness	18.0	4.80	16.0	<4.10
Calcium Hardness	30.0	13.0	42.0	11.0

TABLE 17.-Numbers and location of tagged adult cutthroat trout recaptured, Yellowstone River, 1990 and 1991.

	Area tagged		
Area recaptured	(B)	(D)	(E)
(A) Yellowstone Lake	1	1	0
(B) Yellowstone Lake to above LeHardy Rapids	1	2	0
(C) LeHardy Rapids	2	14	4
(D) Below LeHardy Rapids to Sulphur Caldron	4	45	14
(E) Below Sulphur Caldron to Upper Falls	0	1	2

Discussion

Cutthroat trout spawned throughout the study area, although redd abundance varied among sections. Cutthroat trout fry were also found throughout the river in varying abundances.

Spawning and emergence occurred an estimated 2 weeks later in 1991 than in 1990. By 15 July 1990, most fry were hatched and some had emerged (Jones et al. 1991). On July 15, 1991, most fry were probably eyed or hatched but some were still uneyed. Later emergence could increase pre-emergent fry mortality, because more fry would be in the gravel during the fishing season.

Fishing regulations and difficulty of access to the east side of the river provide some protection of pre-emergent fry from angler wading. The 15 June opening date potentially reduces wading frequency and protects pre-emergent fry for part of their development, though the stage of fry development will vary depending on timing of spawning and water temperatures during incubation. Angler-related mortality would not occur within the 14-km river reach closed to angling and few redds would be waded on along the east bank because few anglers use this area.

Water quality of Sour, Cottongrass, and Otter creeks and warm temperatures of Alum Creek apparently preclude their use by cutthroat trout, whereas Thistle, Trout, and Elk Antler creeks support cutthroat trout reproduction. The presence of juvenile cutthroat trout in Thistle, Trout, and Elk Antler creeks indicates that these are resident populations or that juveniles rear in the tributaries before moving into the Yellowstone River. Cutthroat trout reproduction in these creeks is limited relative to that in the Yellowstone River, however.

Future Reports

Detailed results of this study will be presented in a forthcoming Master of Science thesis by Barbara M. Kelly, Montana State University, Bozeman.

LAMAR RIVER

The Lamar River has traditionally supported one of the most popular stream fisheries in Yellowstone National Park. Since 1973, the section of the Lamar River between Cache Creek and the confluence with the Yellowstone River (Figure 21) has been managed under a catch-and-release-only regulation. In 1987, the catch-and-release area was extended upstream to Calfee Creek. In the mainstream Lamar River and tributaries upstream from and including Calfee Creek, two fish of any size may be creeled.

Historical information and data obtained from the Volunteer Angler Report (VAR) system (Dean and Varley 1974) since 1975 indicate that most angler use in the Lamar River occurs between Cache Creek and Lamar Canyon, referred to here as the valley catch-and-release area. In order to monitor the Lamar River fishery, management studies of the Lamar River have been concentrated within this area. In one of the earliest fishery surveys, Arnold and Sharpe (1967) described habitat and rated fish abundance as "poor to fair" in the Lamar River valley. Subsequently, Jones et al. (1977-1980) used VAR data to evaluate responses of the fishery to catch-and-release regulations. Since 1984, studies of population structure and population size have been conducted in a section of the catch-and-release area of the Lamar River valley (Jones et al. 1985, 1987, 1989-1991). Additional studies of the Lamar River have involved a synthesis of data from previous studies (Jones et al. 1991) and responses of the fishery following the 1988 fires in Yellowstone Park (Postfire Studies, this volume).

Monitoring of the Lamar River fishery continued in 1991. Study objectives included an assessment of the status of the trout populations in the Lamar River valley catch-and-release area, and an analysis of long-term trends in the Lamar River fishery.

Study Area

The Lamar River is the largest tributary of the Yellowstone River within Yellowstone National Park. The 129,500-hectare Lamar River watershed drains the northeastern portion of the park and encompasses almost 15% of the entire park area. From its headwaters in the Absaroka Mountains, the Lamar River flows to the west and north for nearly 70 km before joining the Yellowstone River near Tower Junction. Primary tributaries of the Lamar River are Slough Creek, Soda Butte Creek, Cache Creek, Calfee Creek, Cold Creek, and the Little Lamar River (Figure 21). The electrofishing sample reach in the Lamar River valley extended from the confluence with Soda Butte Creek downstream for a distance of 2.2 km (Figure 22).

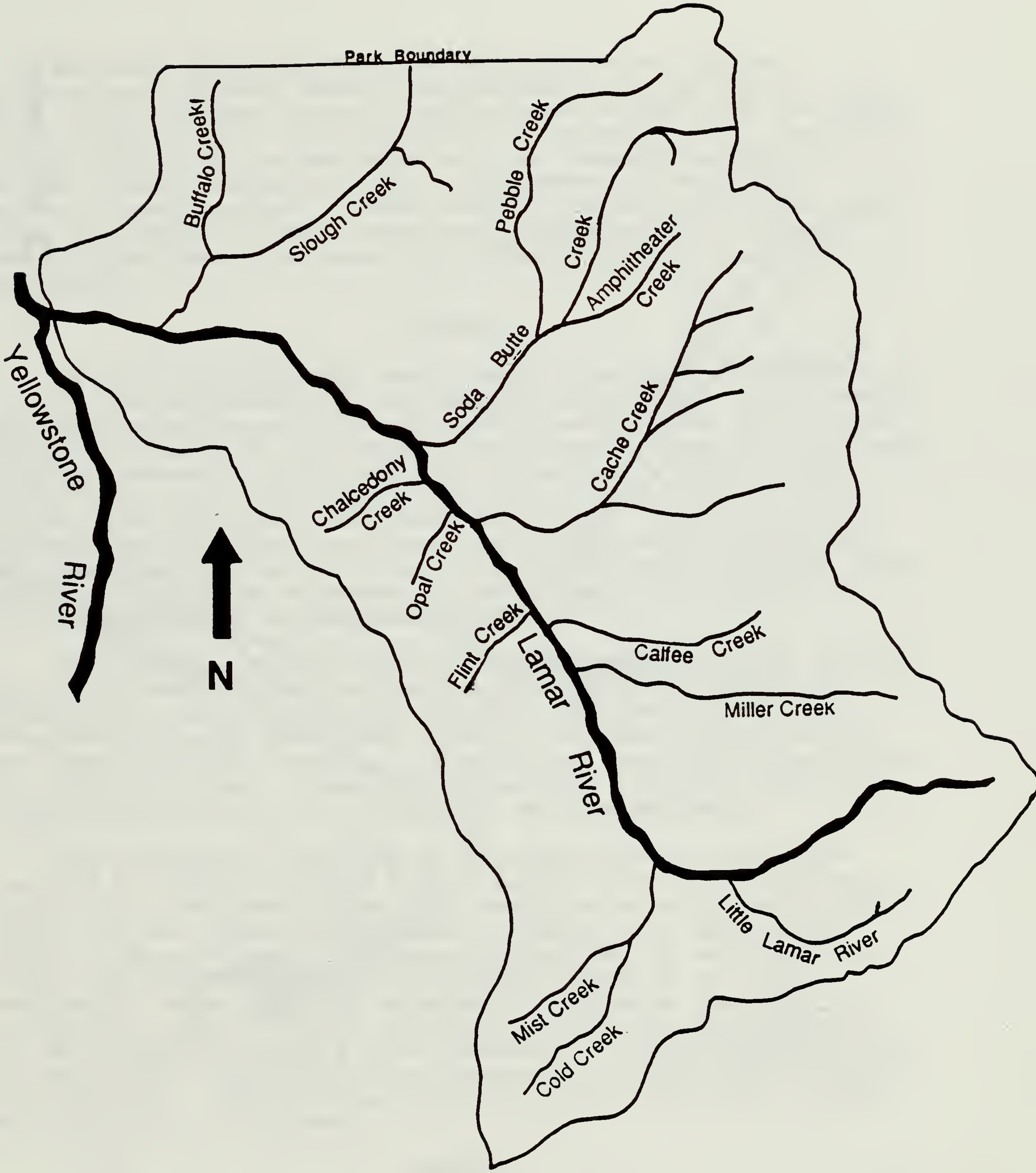


FIGURE 21.-Named streams in the Lamar River drainage, Yellowstone National Park.

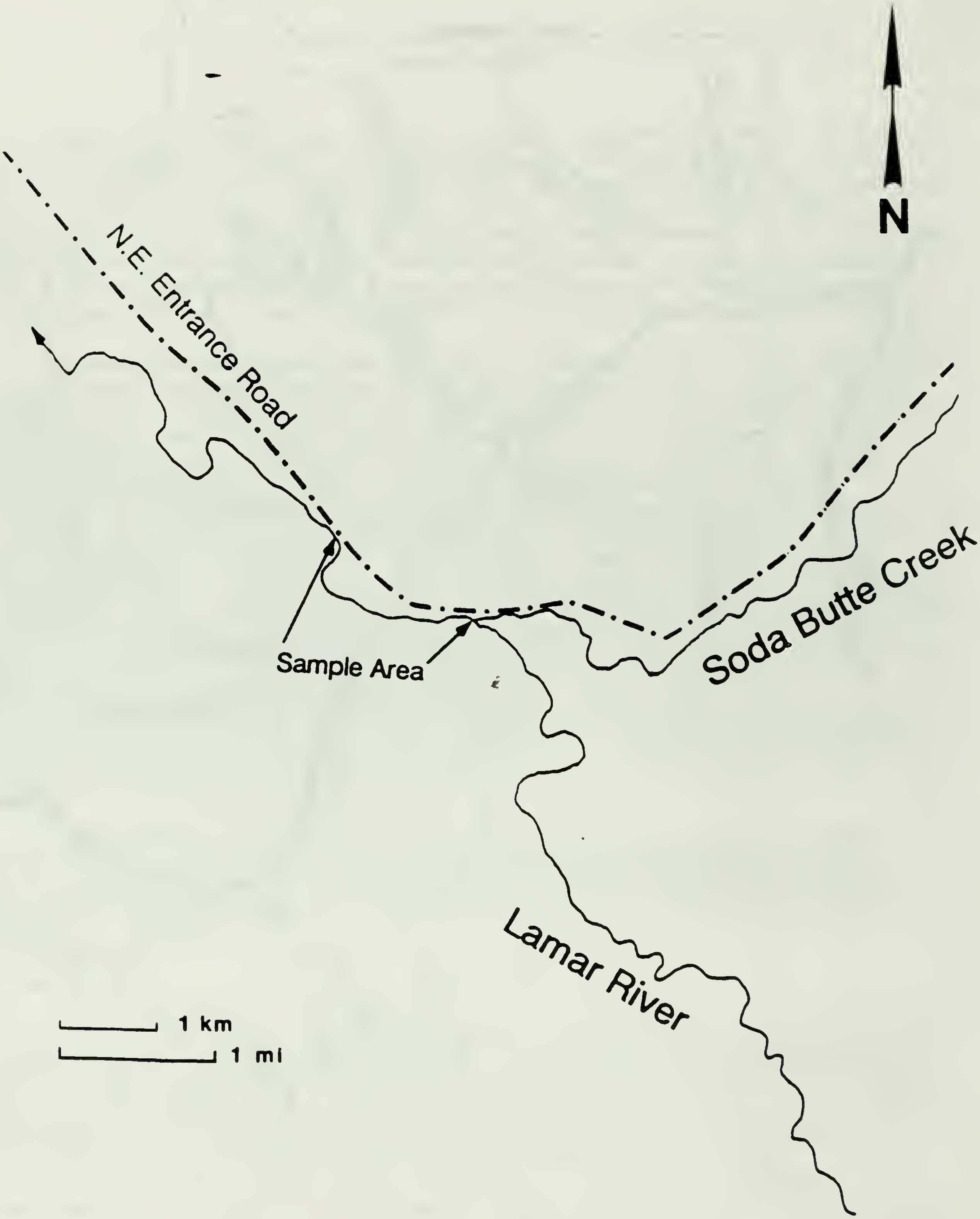


FIGURE 22.-Map of Lamar River valley catch-and-release section showing electrofishing sample area.

The only native salmonid in the Lamar River is the Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*. In 1938, 70,600 rainbow trout *O. mykiss* were stocked into the Lamar River (Varley 1981). Consequently, the current trout population in the Lamar River valley appears to be composed mostly of rainbow trout X cutthroat trout intergrades (D. Shiozawa, personal communication). Other native fish species in the Lamar River are mountain sucker *Catostomus platyrhynchus*, longnose sucker *Catostomus catostomus*, and longnose dace *Rhinichthys cataractae*.

Methods

In the electrofishing study reach, fish were collected from a 4.2-m raft equipped with boom-mounted electrodes. Data from mark-and-recapture electrofishing were used to make an adjusted Peterson estimate of population size (Ricker 1975). All captured fish were measured to the nearest millimeter in total length (TL). Fish from a stratified subsample (based on 25-mm length groups) from the total catch were weighed to the nearest 2 g; scales were collected from these fish for age-growth analyses, but these analyses have not been completed. Mean weight of fish in the subsample was expanded to the estimated population to yield an estimated population biomass.

Proportional Stock Density (PSD) and Relative Stock Density (RSD) were used to examine the length structure of the trout populations sampled by electrofishing. Following guidelines recommendations by Gabelhouse (1984), 203, 381, and 457 mm TL were used as stock, quality, and preferred lengths, respectively, for cutthroat trout. Comparable recommended lengths used for rainbow trout were 229, 406, and 533 mm, respectively.

The influence of angling on the Lamar River fishery was examined by using Volunteer Angler Report (VAR) data compiled since 1976. Analyses of VAR data can provide estimates of total angler use and effort, mean-annual landing rate, mean total length of fish landed, length composition of the angler-caught trout, and total number of fish landed (Jones et al. 1977). Lengths of landed fish are reported on VAR cards in 51-mm increments. When a length of importance to the analyses (e.g., 330 mm) occurred within a 51-mm interval, a uniform distribution (Snedecor and Cochran 1967) was assumed for fish lengths within that interval, and only fish longer than the length of interest were used in the analyses.

Results

Fish

In 1991, 258 rainbow trout X cutthroat trout intergrades were captured in the Lamar River electrofishing study area. Estimated population abundance for trout longer than 100 mm was

1,761 (95% confidence limits, 783-4,252 fish), or approximately 309 trout/hectare. Mean total length of trout captured in 1991 (300 mm) increased significantly (t-test, $P < 0.05$) over the 1990 sample (287 mm). The PSD and RSD values for 1991 were 9 and 2, respectively. Although PSD has generally declined since 1984, RSD values have been relatively stable. Examination of length frequencies shows that nearly 45% of the intergrade trout captured in 1991 were longer than 300 mm TL, and the largest cutthroat trout captured by electrofishing was caught in 1991 (Figure 23). Similarities in population structure since 1988 indicate little change in the proportions of large fish.

Mean weight of 257 rainbow trout X cutthroat trout intergrades collected in 1991 was 307 g. This yielded an estimated biomass of 95 kg/hectare in the study section. In 1990, estimated biomass for this reach was about 53 kg/hectare. Although estimated biomass and population abundance in 1991 were the second-highest to date, they were only one-third the values observed in 1988 (Jones et al. 1989).

In each of the past 4 years, a few fish that appeared to be rainbow trout have occurred in the electrofishing sample. In 1991, 15 of these fish were captured (mean total length, 301 mm). Mean weight and condition factor (K) were 312 g and 1.06, respectively. From 1988 to 1990, rainbow trout PSD in the electrofishing samples was 0 because no rainbow trout longer than the suggested quality length (Gabelhouse 1984) of 406 mm TL were captured; with the capture of a longer individual in 1991, however, PSD increased to 11.

In addition to the salmonids, 6 mountain suckers ranging from 133 to 184 mm in length (mean, 159 mm) and 10 longnose dace ranging from 58 to 106 mm in length (mean, 82 mm) were captured by electrofishing in the Lamar River in 1991.

Anglers

In 1991, the Lamar River was the ninth-most-popular fishery in Yellowstone National Park and sustained slightly over 2% of the estimated parkwide angler use (Table 3). In 1991, an estimated 2,260 anglers spent 10,700 h fishing the Lamar River between Lamar Canyon and the confluence with Calfee Creek. Returns from VAR cards indicated that the estimated mean-annual landing rate in this portion of the Lamar River (1.08 fish/h) increased slightly over the 1989 landing rate of 1.01 fish/h but was unchanged from the 1990 landing rate (1.1 fish/h). Although the 1991 landing rate was nearly 0.5 fish/h less than the mean landing rate for the period from 1976 to 1991 (1.52 fish/h), the general decline noted in landing rate since 1976 may have ended (Figure 24).

In contrast to the pattern seen for landing rate, estimated mean total length of trout landed in the Lamar River valley in

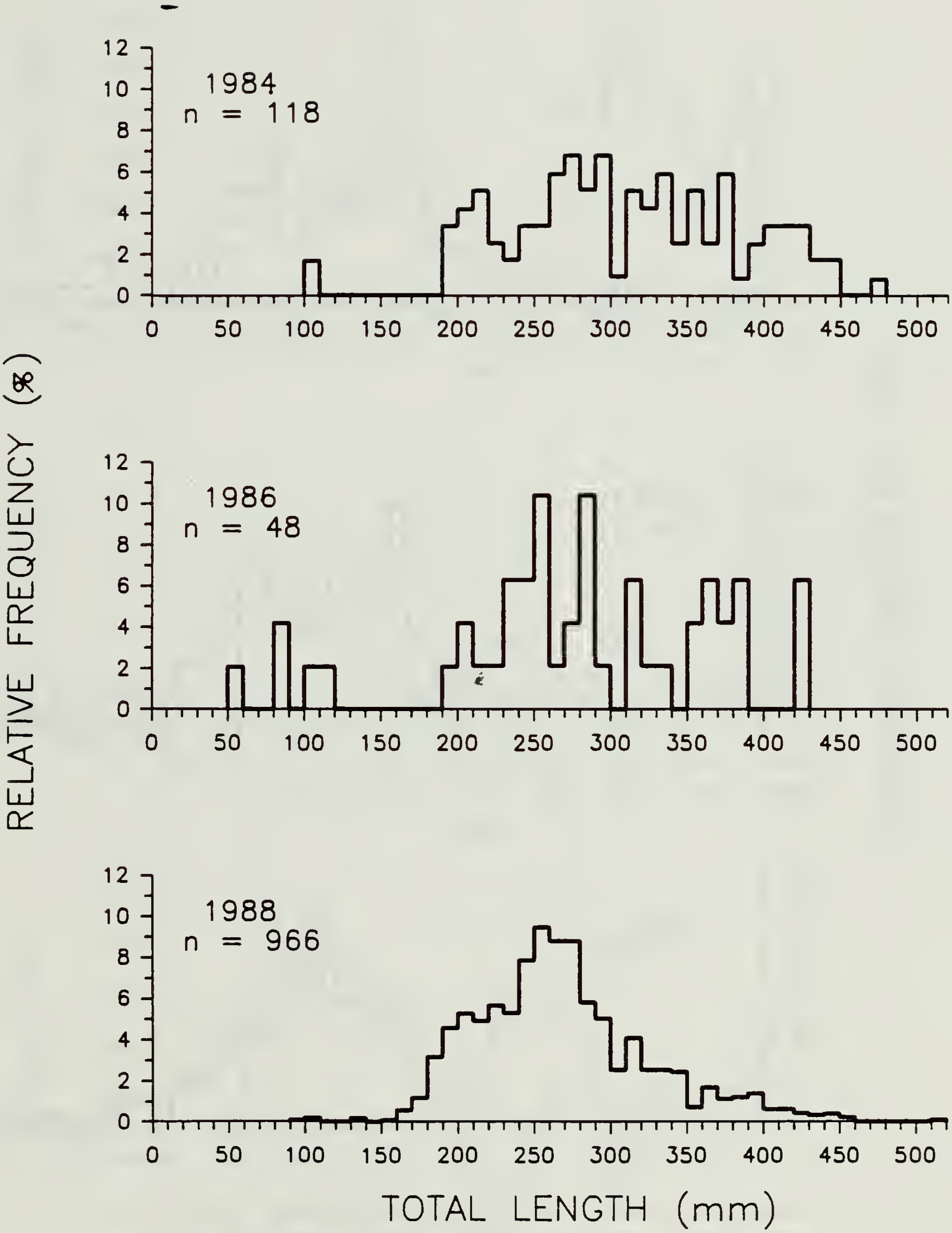


FIGURE 23.-Length-frequency distributions of cutthroat X rainbow trout intergrades captured by electrofishing, Lamar River, 1984-1991.

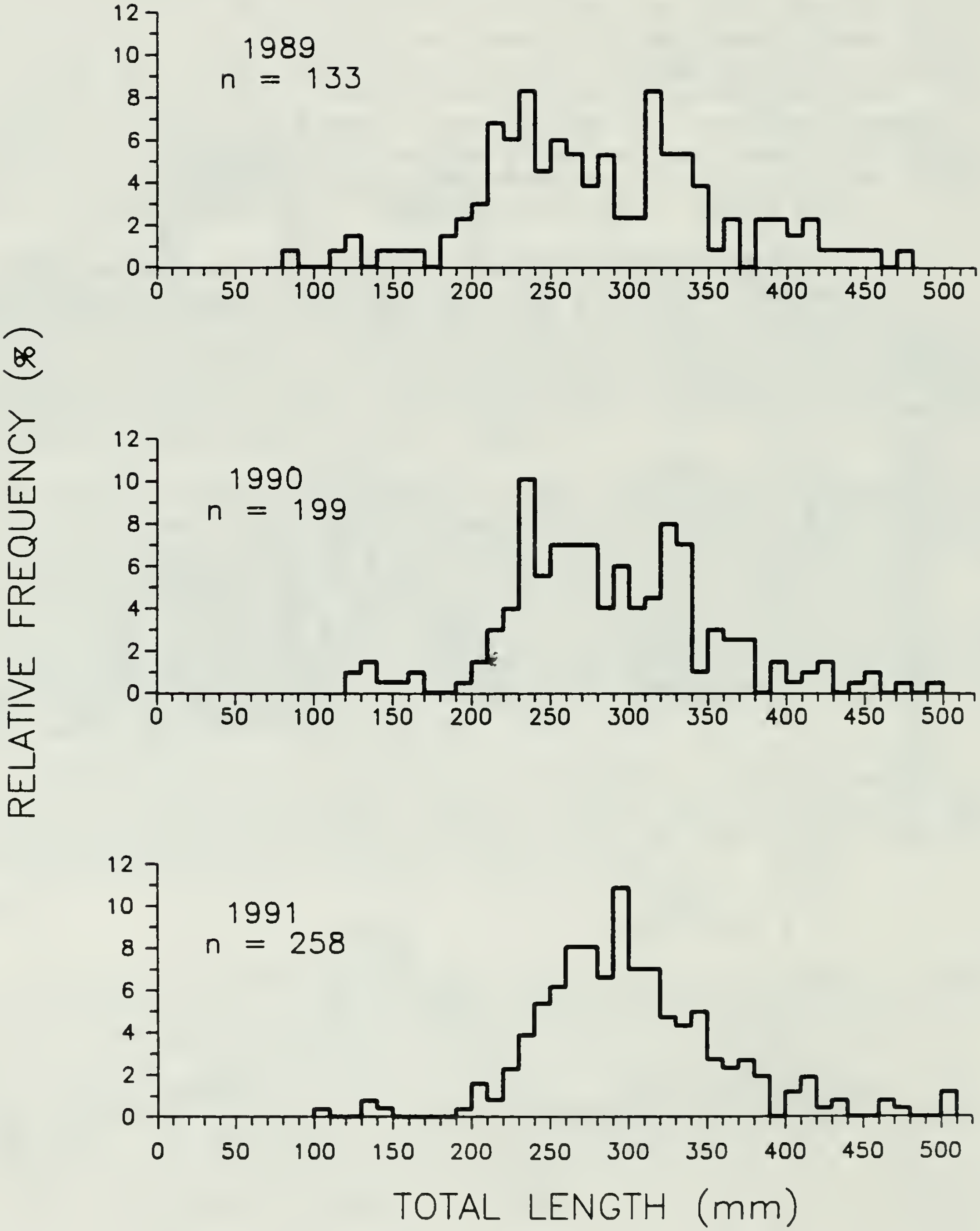


FIGURE 23.-Continued

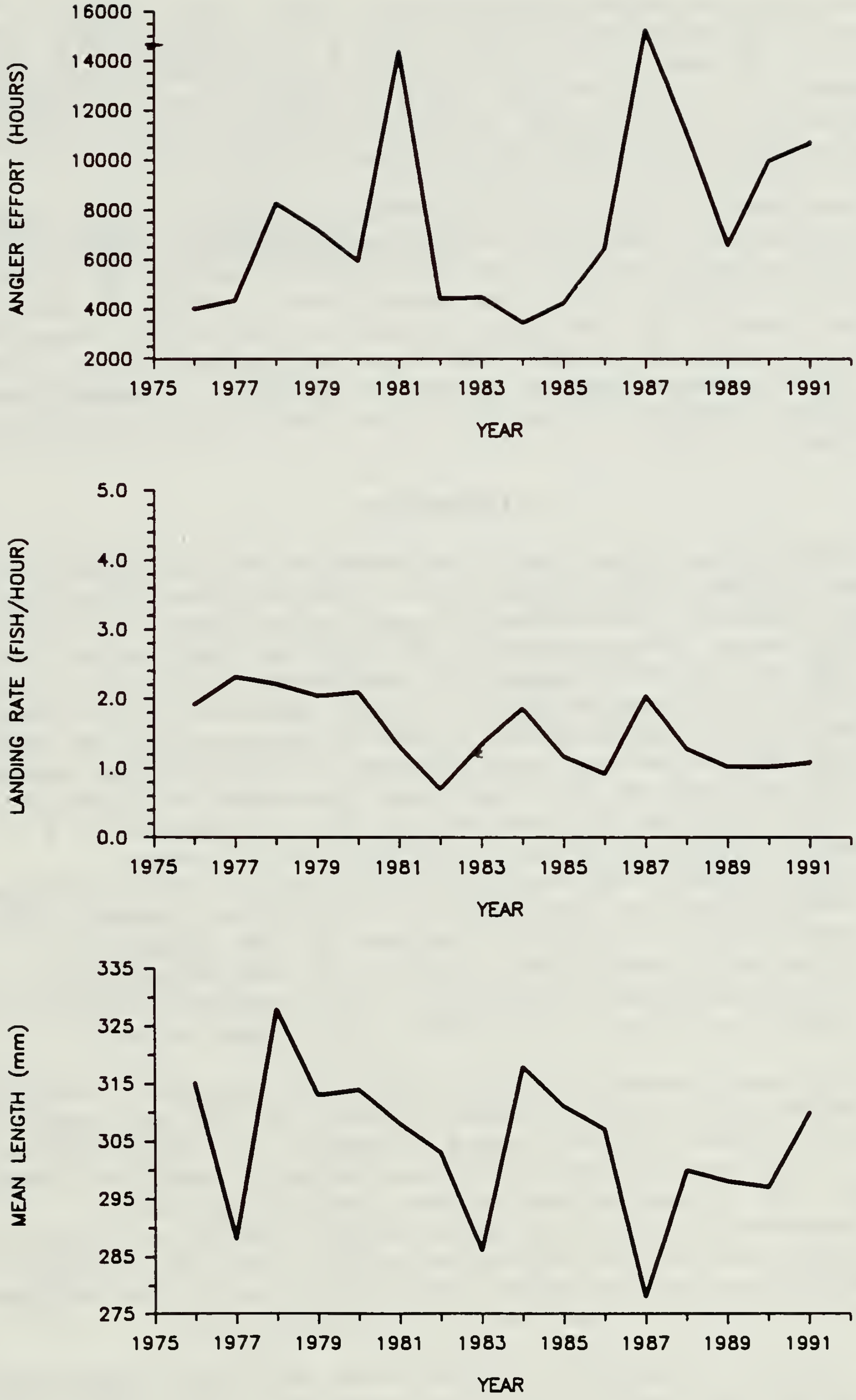


FIGURE 24.-Angler statistics for the catch-and-release section of Lamar River valley, 1976-1991.

1991 was slightly above the long-term (1976-1991) mean (Figure 24). Despite the variability in average length of landed trout during the past 13 years, almost one-third of the fish landed were ≥330 mm TL. This trend continued in 1991 when an estimated 4,100 trout longer than 330 mm were landed in the catch-and-release section of the Lamar River.

The estimated total of 11,500 trout landed in the Lamar Valley in 1991 was similar to the average-annual catch for the period 1976 to 1991 (11,361 trout landed). As in the trends for angler hours, landing rate, and mean total length of fish landed, total annual catch in the Lamar River has exhibited considerable variability. Because landing rate was relatively low in 1991, an increase in the total number of trout landed (in comparison to 1989 and 1990) resulted primarily from the higher-than-average angler effort in 1991.

Discussion

Electrofishing data from the intergrade cutthroat trout populations in the Lamar River have revealed few definite trends. Since 1989, however, mean length, estimated population size, and estimated biomass have increased in the electrofishing reach. Although PSD values have generally declined since 1984, length-frequency distributions suggest a shift towards large trout. This apparent contradiction in length structure can be explained by increased abundance and mean length of the "stock-length" fish (between 203 and 381 mm TL) when the abundance of "quality-length" trout (between 381 and 457 mm TL) increased at a proportionately smaller rate. Differences in annual electrofishing effort and variability in sampling conditions have probably contributed to the lack of definitive trends. For example, turbid water in 1991 resulted in low recapture efficiency and wide confidence limits for the population estimate. Despite this variability, our results indicate that the Lamar River contains a thriving trout population.

Although mean-annual landing rate has generally declined in the Lamar River since 1976, landing rate in 1991 was higher than in most of the other major stream fisheries in Yellowstone Park (Table 3). The Lamar River continues to be a popular fishery, and in 1991, an estimated 80% of the anglers in the catch-and-release area of the Lamar River landed at least one trout. Angler expertise and satisfaction with the overall angling experience on the Lamar River were among the highest reported on Yellowstone National Park (Table 3).

Some of the variability in the data on trout populations in the Lamar River may result from interactions with trout populations in Soda Butte Creek. Currently, the Lamar River and Soda Butte Creek are managed under different angling regulations; although there are no barriers to fish movement between these contiguous streams (Figure 22), their trout populations have been considered distinct. Fish longer than 330 mm are susceptible to harvest in Soda Butte Creek and large trout from the Lamar River would be harvestable if they entered Soda Butte Creek. Although the proximity of the current sampling reach to the confluence with Soda Butte Creek could obscure detection of interactions between the two populations, electrofishing recapture data suggest that the number of fish that move between the two streams is small. The catch-and-release regulation for this section of the Lamar River undoubtedly contributes to the continued survival of these wild trout populations.

SODA BUTTE CREEK

Soda Butte Creek, located in the northeastern corner of Yellowstone National Park, is the third-largest tributary of the Lamar River. Although Soda Butte Creek originates outside the park near Cooke City, MT, most of the watershed (19,500 hectares) is located within the park. The Northeast Entrance highway parallels the stream and provides convenient access for anglers to fish in wide, picturesque meadows and forested valleys surrounded by steep mountains.

Historically, native species in Soda Butte Creek included Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*, mountain sucker *Catostomus platyrhynchus*, longnose dace *Rhinichthys cataractae*, and longnose sucker *Catostomus catostomus* (Varley and Schullery 1983). Between 1920 and 1943, more than 4.5 million cutthroat trout were stocked into Soda Butte Creek to supplement resident stocks. In addition, 100,000 rainbow trout *Oncorhynchus mykiss* were stocked into this stream in 1937 (Varley 1981) and apparently interbred with the cutthroat trout. Consequently, the current salmonid population is composed of cutthroat trout introgressed with rainbow trout genes (Loudenslager and Gall 1981). Since 1982, there have been angler reports of nonnative brook trout *Salvelinus fontinalis* being caught in the upstream portions of Soda Butte Creek. Because brook trout can competitively exclude cutthroat trout from some streams (Jones et al. 1986), their presence in the headwater areas of Soda Butte Creek needs to be determined.

Because numerous human-caused disturbances have occurred in headwater areas of Soda Butte Creek outside the Park, there has been a long history of investigations of changes in the stream environment. Seamans (1940), Sharpe and Arnold (1966), and Jones et al. (1982) considered unstable stream channels and lack of pools to be important influences on the fish communities of Soda Butte Creek. Later studies (Decker-Hess and White 1987; Jones et al. 1989-1991; Postfire Studies, this volume) examined aquatic habitat in relation to changing streamflow patterns or effects associated with forest fires.

Most studies of aquatic communities in Soda Butte Creek have examined actual and potential effects of historic and proposed mining activity in the Cooke City area. Degraded aquatic habitat conditions in Soda Butte Creek that were initially described by Mills and Sharpe (1968) have been reexamined periodically (Dean and Mills 1970, 1971; Dean 1972; Duff 1972; Jones et al. 1982). Extensive water chemistry analyses (Dean and Mills 1971; Dean 1972; Pickett and Chadwick 1973; Hill 1977) and macroinvertebrate collections (Mills and Sharpe 1968; Pickett and Chadwick 1973) were performed during the same time period. Jones et al. (1977-1982, 1985-1990) continued to monitor responses of the Soda Butte Creek fishery to changes in water quality of effluents from the mine tailings. As part of the overall study goal of determining effects of the mining activity on aquatic resources downstream in the park, a water chemistry and macroinvertebrate monitoring program begun in 1984 continues to the present (Mangum 1986a, 1988, 1990, 1992).

Angling regulations for Soda Butte Creek have generally been less restrictive than those of most other cutthroat trout fisheries in the park and, in conjunction with easy access to the stream and proximity to Cooke City, may contribute to the traditional popularity of Soda Butte Creek. Before 1987, the daily creel limit in Soda Butte Creek was two fish of any size. Concern about excessive harvest was expressed in the late 1970s, and a catch-and-release regulation recommended for Soda Butte Creek (Jones et al. 1979) but not implemented. In 1987, the harvest regulation was changed to include a 330-mm minimum-size restriction.

In the past 3 decades, fish populations from six sections of Soda Butte Creek have been surveyed (Sharpe and Arnold 1966; Jones et al. 1982, 1984 - 1991). Four of these areas have been sampled several times and have been used for long-term examination of the fishery. Fish populations at three of these four study sites were again sampled in 1991. Study objectives include estimation of the abundance of trout in different sections of Soda Butte Creek and description of the population structure. This report also examines long-term trends in the Soda Butte Creek fishery.

Study Area

The Soda Butte Creek watershed is a product of Eocene Absaroka volcanic flows followed by extensive Pleistocene glaciation. Isolated limestone outcrops and evidence of massive landslides occur throughout the drainage. Within the park, the 26-km reach of Soda Butte Creek is separated into two sections of similar length by Icebox Canyon (Figure 25). This canyon may be a barrier to upstream fish movement (Sharpe and Arnold 1966; Jones et al. 1982). Upstream from Icebox Canyon, Soda Butte Creek flows through a narrow, V-shaped, densely forested valley that is bordered on the east by Abiathar Peak and on the west by Barronette Peak. Downstream from Icebox Canyon, Soda Butte Creek meanders through large meadows enclosed in a wide, U-shaped valley, and mainstem discharge is increased substantially by streamflow from Pebble Creek and Amphitheater Creek.

In 1991, three electrofishing study reaches were selected in Soda Butte Creek. The 2.3-km Footbridge section, which extends from the Lamar River trail footbridge downstream to the confluence with the Lamar River (Figure 25), has been sampled on seven previous occasions. The Icebox Canyon section encompasses a 1-km reach of Soda Butte Creek just upstream from Icebox Canyon (Figure 25). This reach was initially surveyed for fish in 1987,

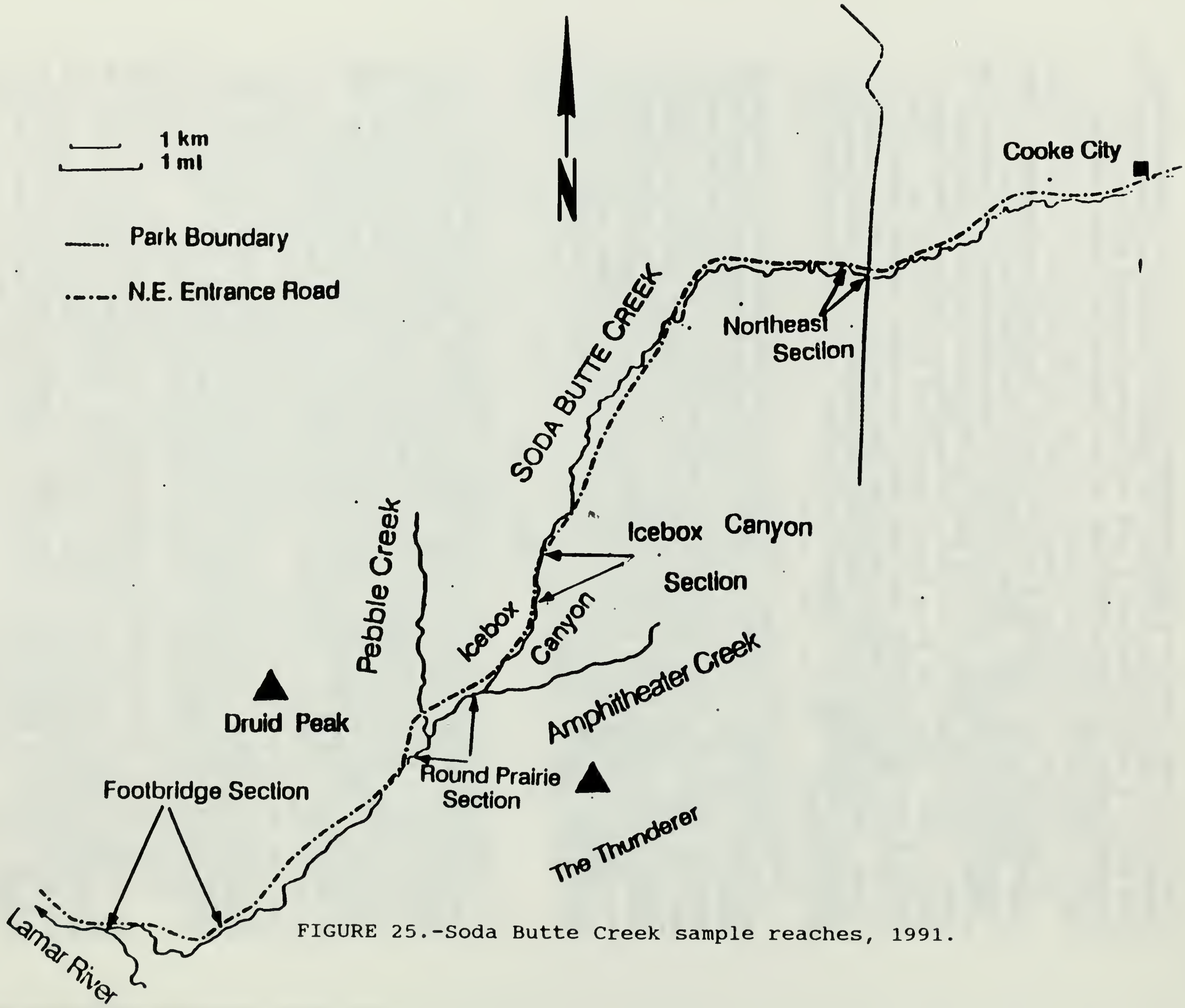


FIGURE 25.-Soda Butte Creek sample reaches, 1991.

and has been resurveyed annually since 1988 to monitor recovery from an accidental rotenone treatment in August 1988 that eliminated almost all of the trout in this stream section (Jones et al. 1989). The Northeast Boundary sample area begins near the Northeast boundary of the park and extends downstream for 305 m; this reach was sampled in 1981 and annually since 1984.

Methods

In 1990, electrofishing in the Footbridge section was conducted from a 4.3-m rubber raft that contained boom-mounted electrodes, a portable generator, and a pulsed DC shocking system. Captured salmonids were measured to the nearest 1 mm total length (TL), marked with a fin clip, and stratified into 25-mm length groups. Five fish from each length group were individually weighed to the nearest 2 g and had scales collected for age-growth analyses; however, age analyses based on scales have not been completed for the Footbridge section. Data collected from other fish species was restricted to length measurements.

In the Icebox Canyon section, two Coffelt BP-1 backpack electroshockers were used to capture fish. Captured trout were measured to the nearest 1 mm TL, weighed to the nearest 2 g, and marked with a fin clip. Scale samples for age and growth analyses were collected from a stratified subsample of 25-mm length groups. Equipment and techniques used in the Northeast Boundary section were similar to those used in the Footbridge section, except a 2-m plastic boat was used to carry shocking equipment and the electrodes were hand-held rather than boom-mounted.

In 1991, trout population abundance and biomass in the Footbridge and Northeast Boundary sections were estimated by applying the adjusted Petersen formula (Ricker 1975) to mark-and-recapture electrofishing results. In the Icebox Canyon section, the main objectives were to examine cutthroat trout population structure and to compare relative abundance to data from previous years; because only a single electrofishing pass was made, population abundance could not be estimated.

Proportional Stock Density (PSD) and Relative Stock Density (RSD) indices (Gabelhouse 1984) were used to examine length structure of the cutthroat trout populations in Soda Butte Creek. For cutthroat trout, PSD recommended by Gabelhouse(1984) is the proportion of fish in the population longer than 203 mm TL (stock length) that are also longer than 381 mm TL (quality length), and RSD is the proportion of fish in the population longer than 203 mm TL that are also longer than 457 mm (preferred length). Because these length categories for cutthroat trout are generally greater than those found in cutthroat trout from Soda Butte Creek, stock, quality, and preferred lengths in this study were reduced to 153, 254, and 330 mm, respectively.

The Volunteer Angler Report (VAR) was used to provide data from the Soda Butte Creek fishery, including estimates of total angler use and effort, landing rate, mean total length of fish landed, length composition of the angler-caught trout, and total number of fish landed annually since 1977. Data from VAR returns from Soda Butte Creek have been divided into two stream sections: from the confluence with the Lamar River upstream to Icebox Canyon (below Icebox Canyon) and from Icebox Canyon upstream to the Northeast boundary of the park (above Icebox Canyon). On VAR cards, mean lengths of landed fish are reported in 51-mm intervals. A uniform distribution (Snedecor and Cochran 1967) was assumed for lengths of landed fish within each interval. If a particular mean length of interest (e.g., 330 mm) occurred within a 51 mm interval, only fish longer than the length of interest were used in the analysis. Significant ($P < 0.05$) differences in growth rates of trout captured by electrofishing among years were detected with one-way ANOVA and Duncan's Multiple Comparison Test (Zar 1984), and differences ($P < 0.05$) in VAR statistics between the periods 1977-1986 and 1987-1990 were determined with a *t*-test.

Results

Fish

Footbridge section.-In 1991, 366 cutthroat trout were captured in the Footbridge electrofishing reach. The population estimate of 1,004 cutthroat trout (95% confidence limits, 591-1,922) in 1991 was the second-smallest in 7 years of electrofishing. Mean total length of captured cutthroat trout was 257 mm, and the proportion of the fish ≥330 mm (19.4%) was the highest yet recorded (Figure 26).

Compared to previous years, length-frequency distribution for cutthroat trout in the Footbridge section in 1991 appeared to shift towards longer trout (Figure 27). Record-high PSD and RSD values (65 and 23, respectively) also indicated an increased proportion of longer fish in the electrofishing sample.

Mean weight and condition factor (K) for 364 cutthroat trout were 237 g and 1.08, respectively. Multiplying this mean weight by the estimated population yielded an estimated biomass of 101 kg/km (66.2 kg/hectare) in 1991, nearly identical to the mean biomass for the period 1984 to 1986, but considerably less than values in 1989 and 1990.

In 1991, seven trout that appeared to be rainbow trout were caught in the Footbridge section. Estimated total number of rainbow trout for the footbridge section was 11 (95% confidence limits, 8-19); however, this estimate is probably negatively biased by the single recapture. Mean total length, mean weight, and mean condition factor (K) were 337 mm, 431 g, and 1.05, respectively. Comparable values from the nine rainbow trout

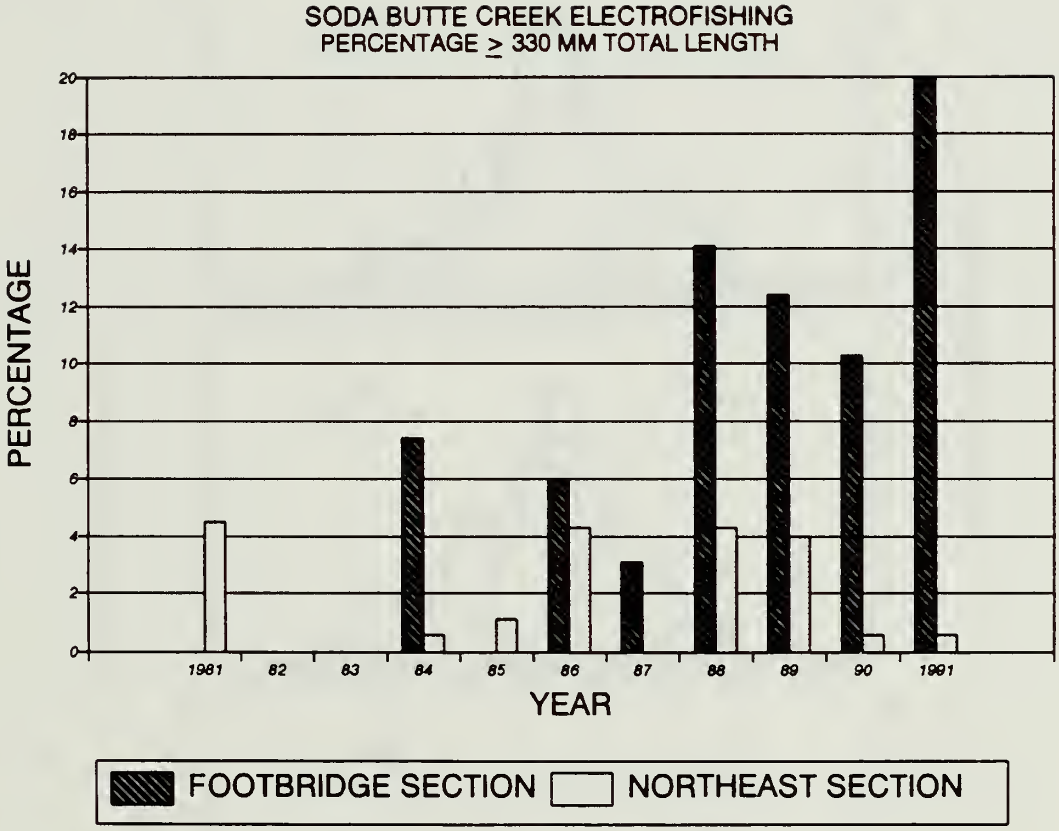


FIGURE 26.-Percentage of cutthroat trout ≥ 330 mm total length in the electrofishing catch, Soda Butte Creek, 1981-1991.

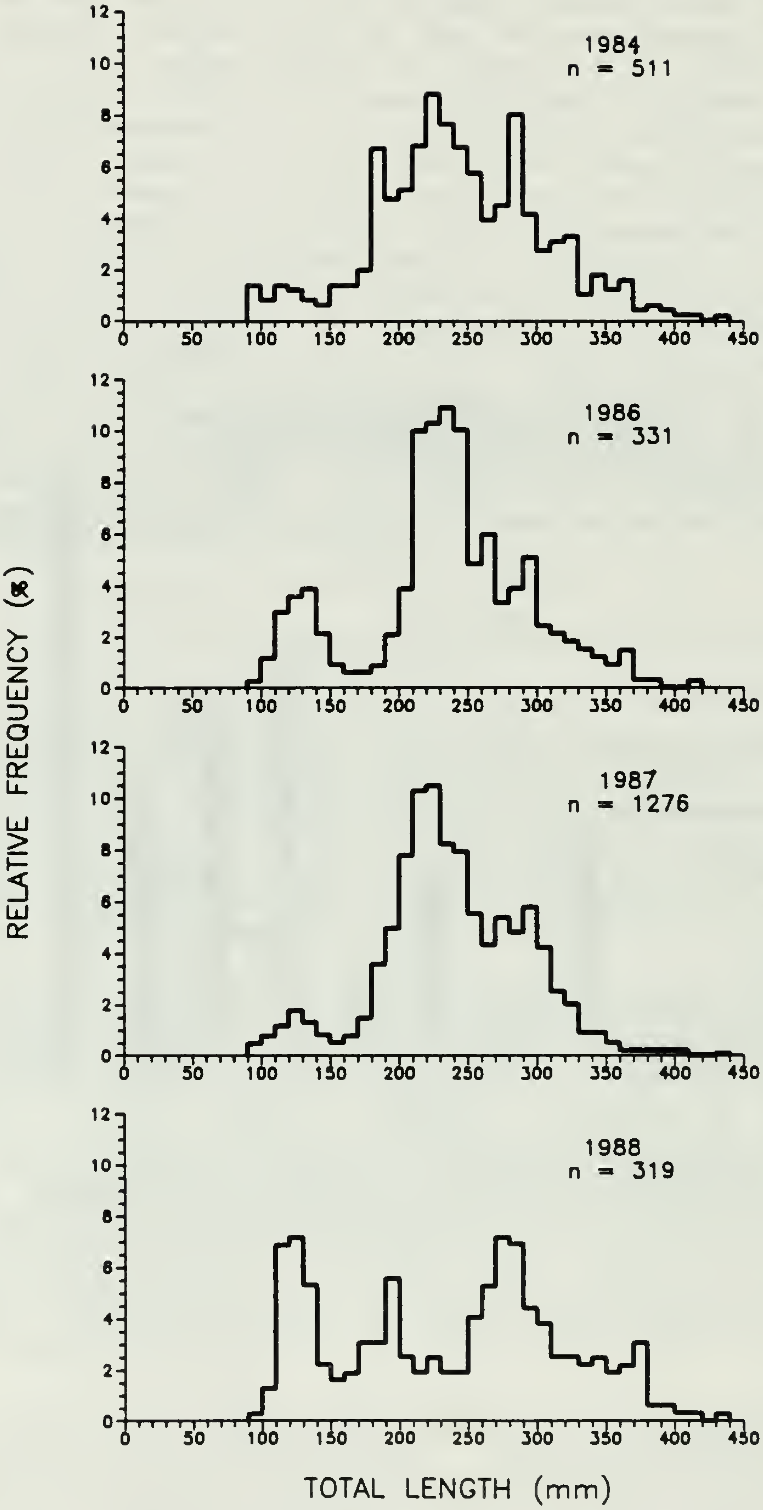


FIGURE 27.-Length-frequency distributions of cutthroat trout captured by electrofishing, Footbridge section, Soda Butte Creek, 1984-1991.

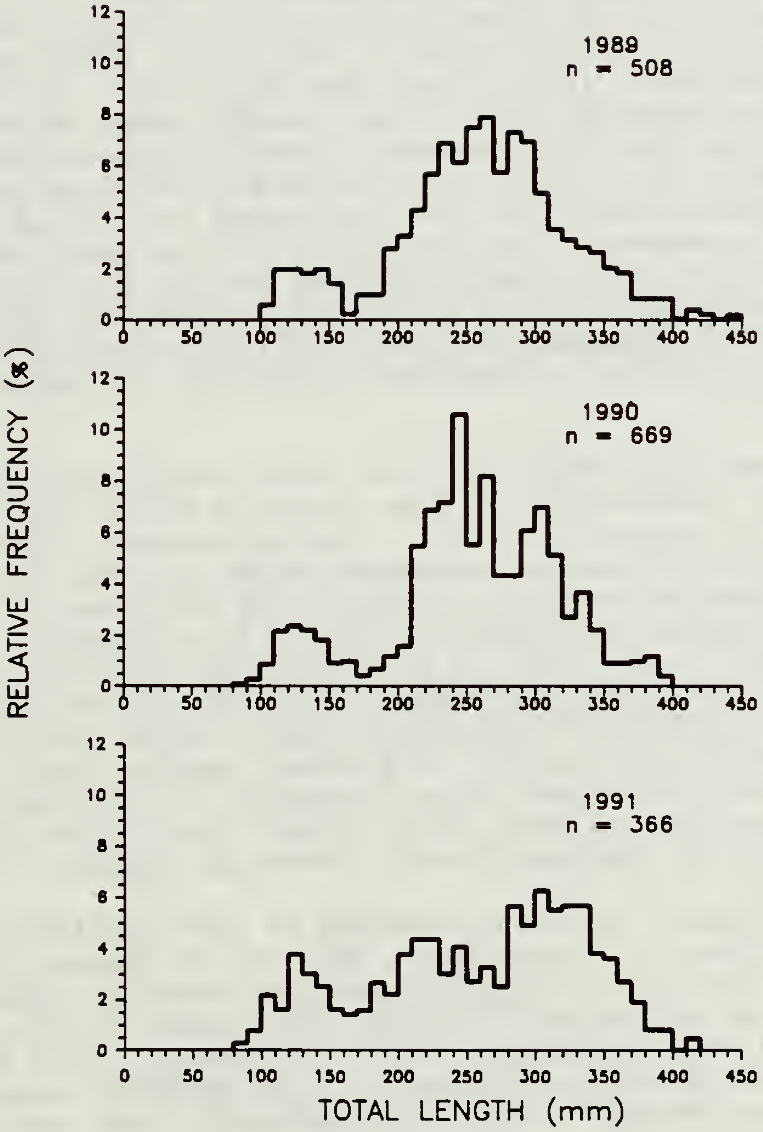


FIGURE 27.-Continued

captured in 1990 were 303 mm, 308 g, and 1.05, respectively (Jones et al. 1991). The increase in mean length in 1991 was also reflected in length-structure indices. The PSD increased from 83 in 1989 to 100 in 1991, and RSD values increased from 8 in 1989 to 43 in 1991.

In addition to the salmonids, 52 mountain suckers and 74 longnose dace were captured in the Footbridge section in 1991. Mean total length of the mountain suckers was 146 mm (range, 87-205 mm) and average length of captured longnose dace was 85 mm (range, 62-116 mm).

Icebox Canyon section.-The abundance (N = 165) of cutthroat trout captured by electrofishing in the Icebox Canyon section in 1991 was the highest in four years of sampling. Mean total length of captured trout in 1991 was 185 mm (range, 75-365), which reversed the decrease in average length noted since 1987 (Figure 28). Values for PSD, however, have declined from 41 in 1987 to 27 in 1991. Similarly, an increase in mean weight to 101 g (N = 158 cutthroat trout) in 1991 indicated an end to the decreasing trend observed since 1987. When this mean weight was applied to the entire 1991 electrofishing catch, there was an estimated biomass of 16.7 kg/km in the study section, nearly double the estimated biomass in 1987 (9.2 kg/km). Condition factor (K) has been variable, but has generally increased since 1987.

Scale analyses indicated that the 1991 sample encompassed five age classes. Almost 75% of the captured trout were classified as 1- or 2-year-old fish. Percentages of age-2 and age-3 trout in the 1991 sample exceeded those of the 1987 sample; however, proportions of age-4 and older fish were small in the 1991 sample. Estimated mean-annual growth in cutthroat captured in 1991 (74 mm/year) and 1990 (73 mm/year) was significantly higher ($P < 0.05$) than that estimated for 1987 (61 mm/year). Mean-annual growth rates of trout captured in 1989 (67 mm/year) were not significantly different from other sample years. These results suggest that cutthroat trout captured in the past two years from this section of Soda Butte Creek grew faster than the fish captured prior to the accidental rotenone treatment in 1988.

Northeast Boundary section.-Because of its proximity to the McClaren mine tailings at Cooke City, MT, the Northeast Boundary section has been the most frequently sampled area of Soda Butte Creek. In 1991, an estimated 462 (95% confidence limits, 241-1,114) cutthroat trout inhabited the study reach. This estimated trout abundance was the second-highest in 9 years of sampling. Mean total length (209 mm) of the 155 captured trout was similar to the long-term (1981-1991) average length (216 mm). Length-frequency distribution for the 1991 sample revealed that 75% of the captured trout were between 150 mm and 250 mm TL and, as in previous years, few (<1%) fish were longer than 330 mm TL (Figure 26). In the Northeast Boundary section, PSD values have

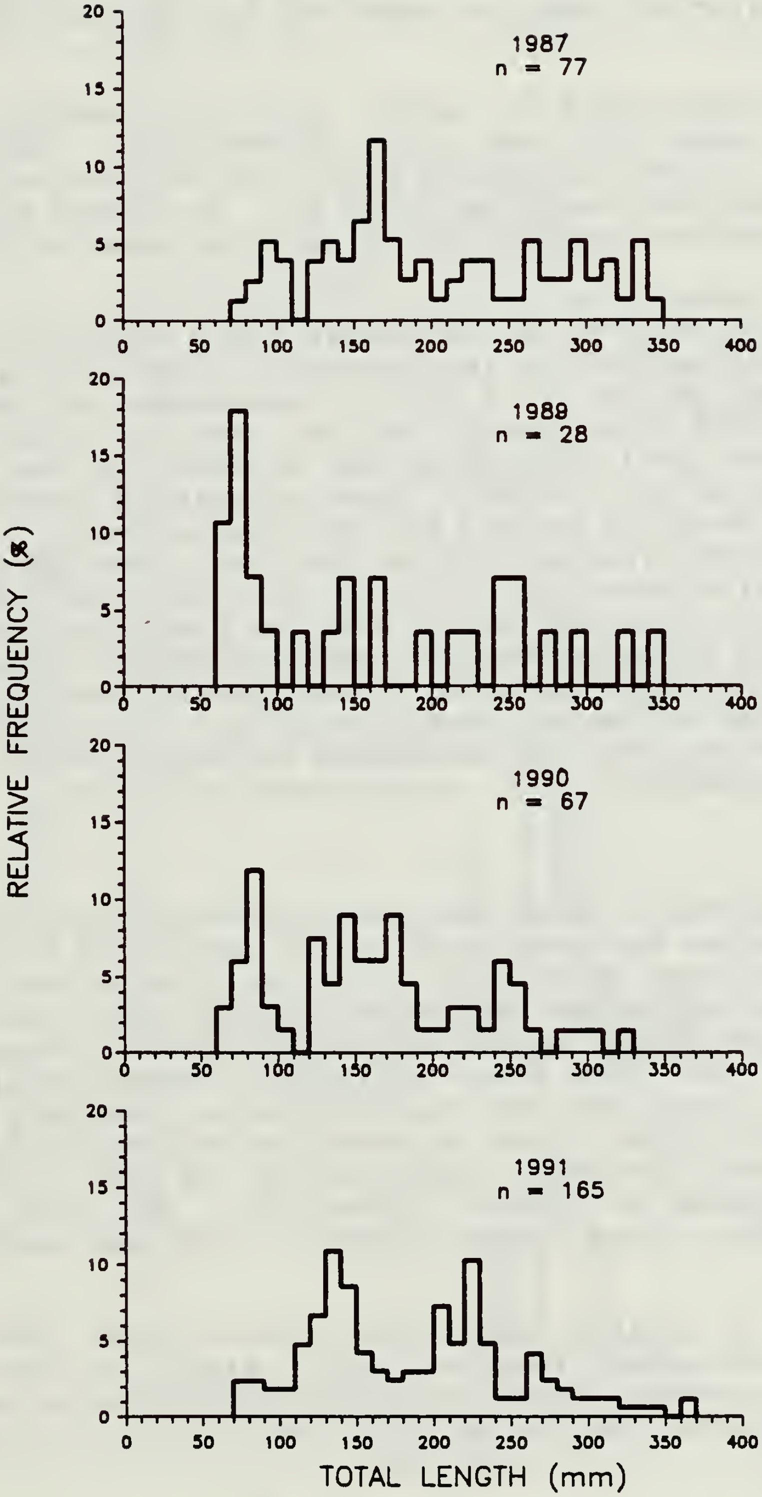


FIGURE 28.-Length-frequency distributions of cutthroat trout captured by electrofishing. Icebox Canyon section, Soda Butte Creek, 1987-1991.

varied among years and declined from 34 in 1990 to 16 in 1991, 50% less than the average PSD of 35 for all nine samples combined; however, PSD has averaged 35% higher under the 330-mm minimum-size regulation than the mean PSD for the period 1981-1986.

Mean weight and condition factor (K) of 152 cutthroat trout captured in 1991 were 122 g and 1.17, respectively. The 1991 condition factor is the highest to date, but average weight remained below the long-term mean (140 g). Estimated biomass in the Northeast Boundary section in 1991 was the same as 1990 (105 kg/hectare).

Age-growth analyses of 66 cutthroat trout captured from the Northeast Boundary section in 1991 revealed five age classes. Estimated mean age in 1991 (2.3 years) increased from the record low observed in 1990 (1.9 years), and was about 0.5 year younger than the long-term (1981-1991) mean age of trout in the electrofishing catch (2.7 years). Back-calculated lengths at annulus I and II were 141 mm and 221 mm, respectively. Examination of length-frequency distributions illustrates the increase in relative abundance of trout in these size ranges (Figure 29) between 1990 and 1991. For the first four growing seasons, estimated annual growth in 1991 (71 mm/year) was nearly identical to the patterns observed in cutthroat trout captured in 1990. Although the estimated growth rates for these two years are the fastest known from the Northeast Boundary section, the increases are not statistically significant ($P > 0.05$).

Anglers

In 1991, Soda Butte Creek was the eighth-most-heavily-fished stream in Yellowstone National Park and an estimated 3,500 anglers spent more than 15,000 hours fishing this stream (Table 3). According to VAR estimates, angler effort has been consistently higher below Icebox Canyon than above Icebox Canyon (Figure 30). In 1991, both areas exhibited a substantial increase in effort over the two previous years, possibly reflecting the increasing trend in parkwide angler use (Table 1). Below Icebox Canyon, estimated angler effort in 1991 (7,826 h) was the second highest on record (Figure 30). The level of annual angler effort above Icebox Canyon in 1991 was surpassed only in 1987.

The decline in landing rate below Icebox Canyon noted since 1988 ended with the modest increase to 1.3 fish/h in 1991. Coupled with high levels of effort, the greater landing rate resulted in the largest estimated total catch (10,300 fish) on record (Figure 31).

Mean length of fish landed below Icebox Canyon in 1991 (260 mm) was similar to the mean for all angling seasons between

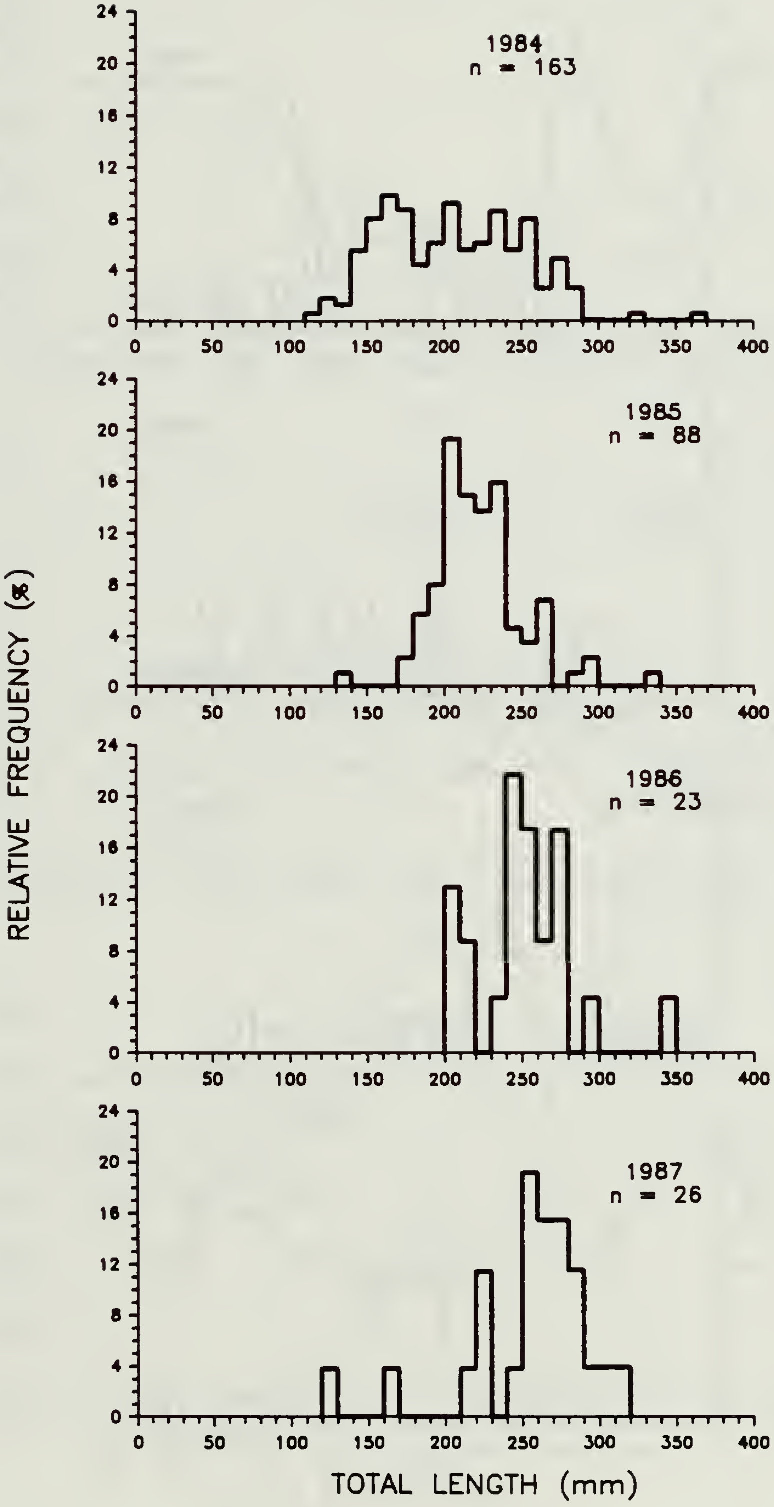
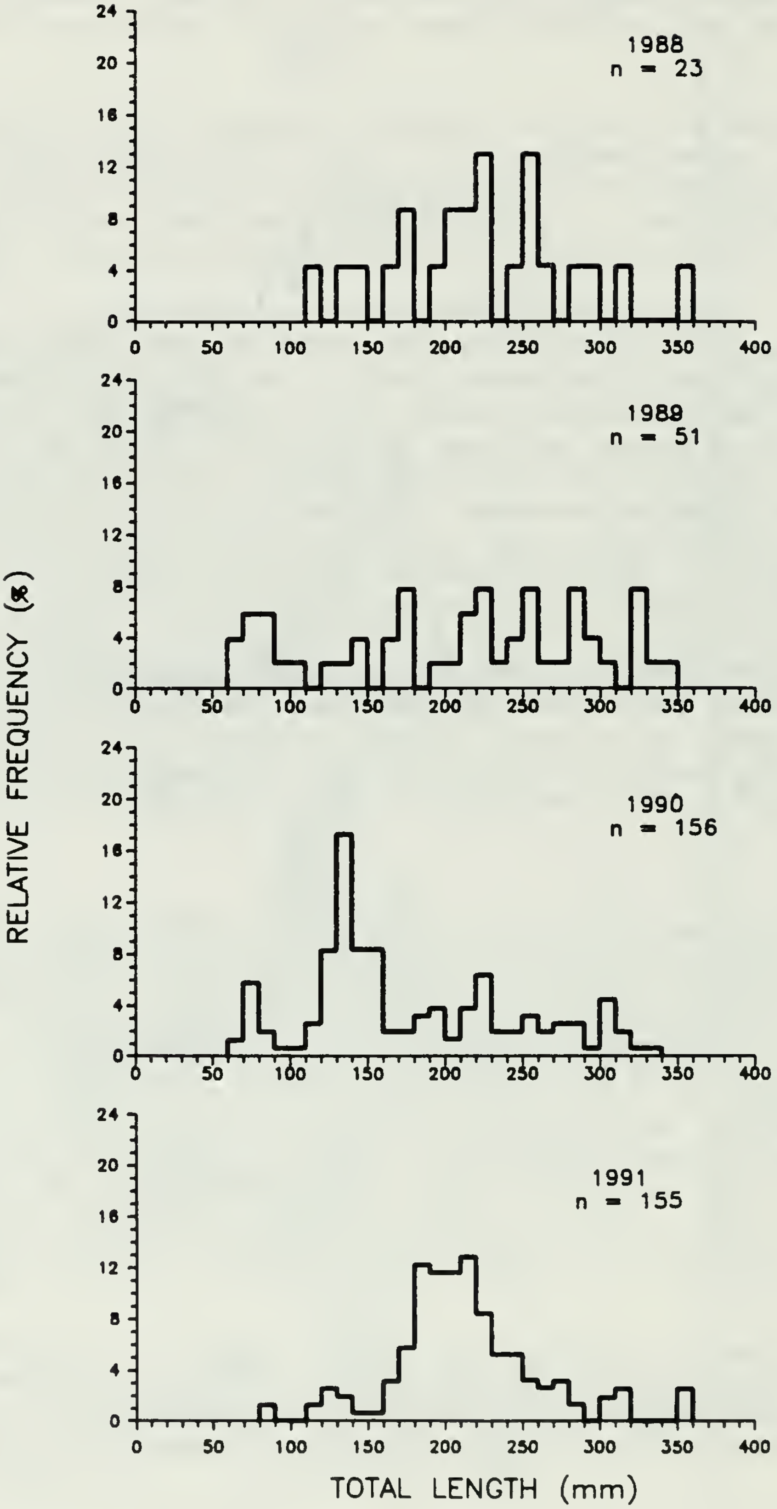


FIGURE 29.-Length-frequency distributions of cutthroat trout captured by electrofishing, Northeast section, Soda Butte Creek, 1984-1991.



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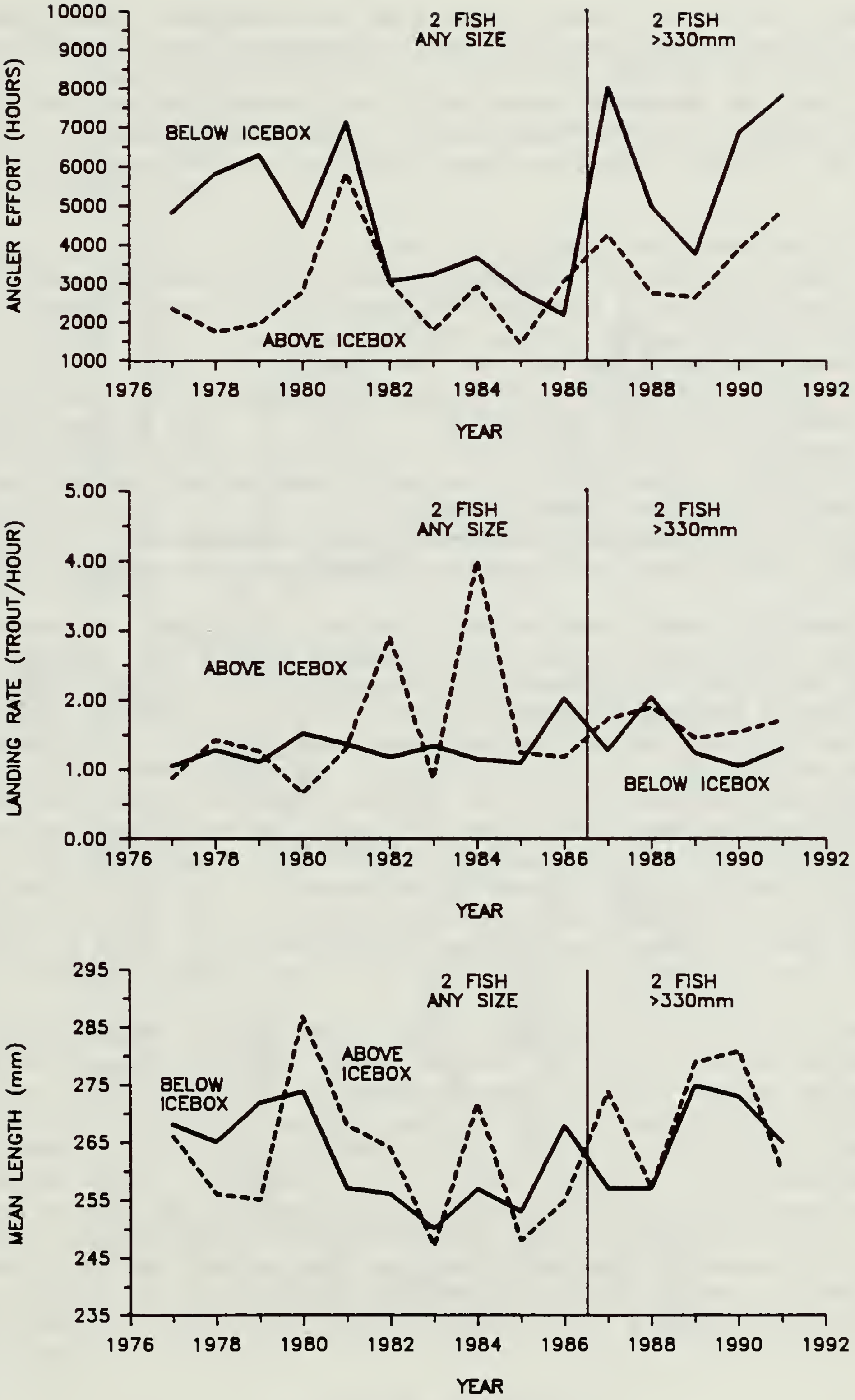

FIGURE 30.-Angler statistics from Soda Butte Creek, 1977-1991.

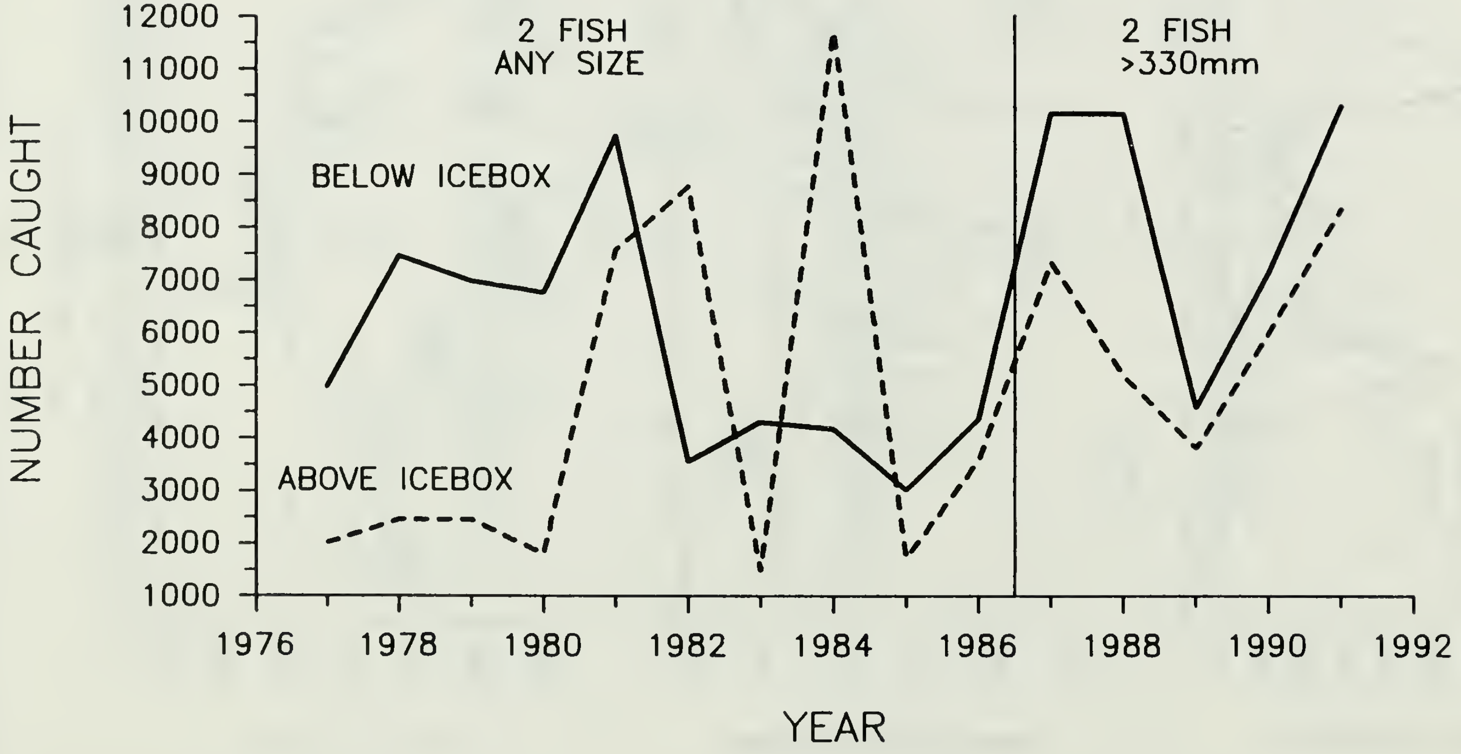

FIGURE 31.-Estimated total catch of trout from Soda Butte Creek, 1977-1991.

1977 and 1991 (Figure 30); but mean length of trout landed below Icebox Canyon has increased since the angling regulation changed in 1987. Approximately 13% of the fish landed in 1991 were ≥330 mm TL, and an estimated 564 trout were creeled in the lower section of Soda Butte Creek. This harvest was nearly 50% greater than the post-1986 estimated average-annual harvest of 388 trout longer than 330 mm.

Above Icebox Canyon, landing rates have generally been higher than those below Icebox Canyon. Prior to 1986, landing rates ranged from 0.65 fish/h in 1980 to a high of 4 fish/h in 1984 (Figure 30). Landing rates have fluctuated by less than 0.5 fish/h since 1987, and the 1991 estimated landing rate (1.7 fish/h) was slightly above the average-annual landing rate for the period 1977 to 1991 (1.6 fish/h). Total number of fish landed above Icebox Canyon has shown a pattern similar to that of landing rates, and appears to be more strongly correlated with landing rate ($r = 0.84$, $P < 0.0001$) than angler effort ($r = 0.64$, $P = 0.01$). Estimated number of trout landed above Icebox Canyon in 1991 was the third-highest between 1977 and 1991 (Figure 31).

Average length of landed fish above Icebox Canyon has varied among years, but has generally increased since 1983 (Figure 30). Mean total length of angler-caught trout in 1991 (265 mm) was identical to the long-term mean length of landed trout above Icebox Canyon. Since the implementation of the 330-mm minimum-size regulation, average length of landed fish above Icebox Canyon has been greater (except in 1988) than the average mean length estimated under the no-size-limit regulation (262 mm). In 1991, approximately 13% of the landed fish above Icebox Canyon exceeded 330 mm TL. Since 1987, an average of 15% of the landed trout have been in this size group. In contrast, a significantly smaller ($t = -2.42$, $P < 0.05$) percentage (mean, 7.8%) of fish landed between 1977 and 1986 were longer than 330 mm.

According to VAR data, approximately 45% of the trout ≥330 mm total length landed above Icebox Canyon were creeled annually prior to 1987. After implementation of the 330-mm minimum-size regulation in 1987, overall harvest of trout above Icebox Canyon decreased by more than 50% (Figure 32). In 1991, an estimated 406 trout were creeled above Icebox Canyon. This was the largest estimated harvest since 1984 (Figure 32) and represented a 35% increase above the average-annual harvest between 1987 and 1991. Current harvest estimates suggest that approximately three times more cutthroat trout longer than 330 mm have been creeled above Icebox Canyon since the more restrictive regulation was instituted.

Discussion

Historical accounts and recent studies suggest that channel stability, sedimentation, macroinvertebrate community structure, and mine-tailing effluents from Cooke City are important factors

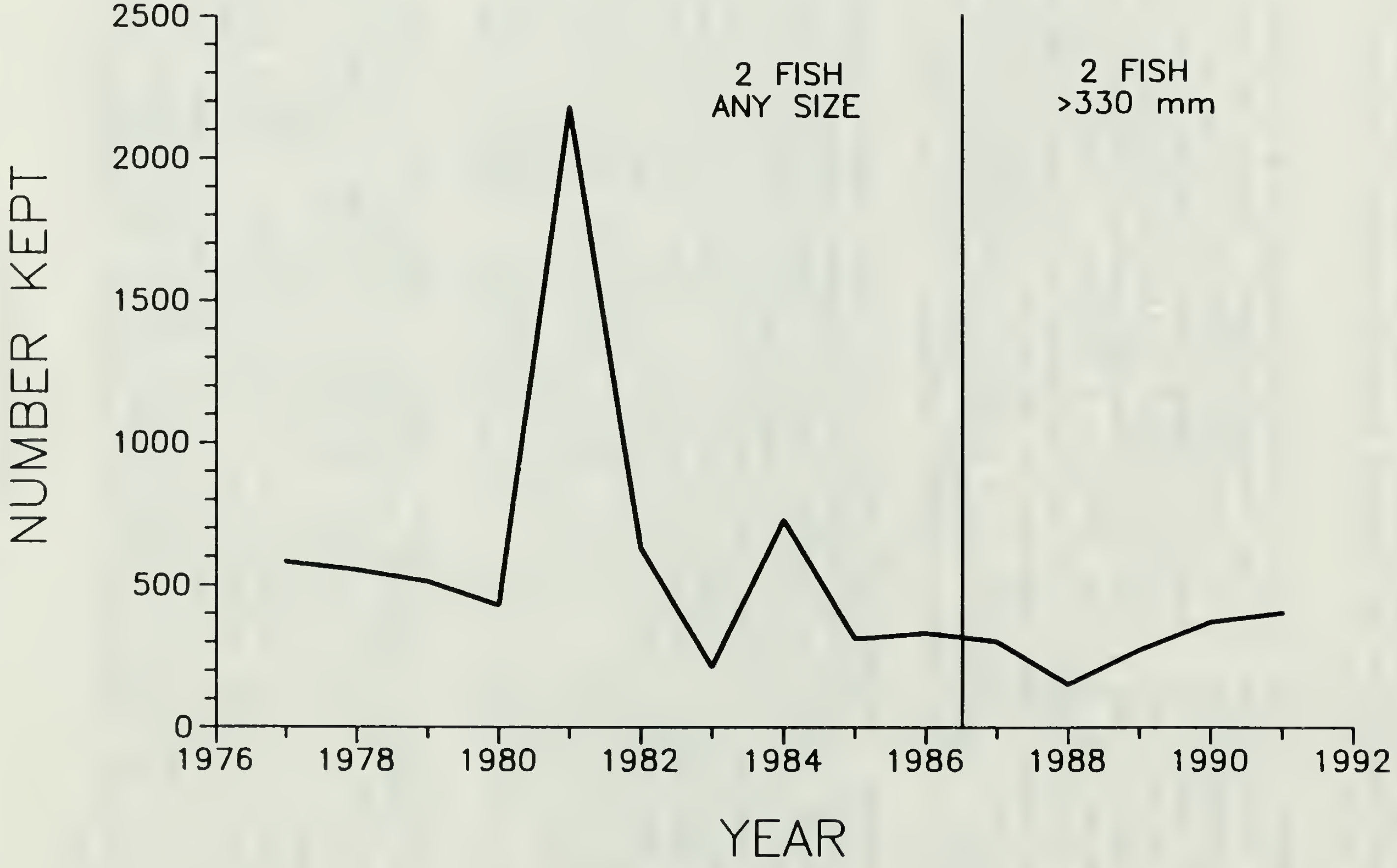

FIGURE 32.-Estimated number of trout harvested from Soda Butte Creek above Icebox Canyon, 1975-1991.

affecting the status of trout populations in Soda Butte Creek (Seamans 1940; Sharpe and Arnold 1966; Mills and Sharpe 1968; Dean and Mills 1971; Hill 1977; Jones et al. 1980, 1982, 1988-1991; Decker-Hess and White 1987; Mangum 1988, 1990, 1992). Examples of stream channel instability have been observed during recent electrofishing studies in the Footbridge section, where gravel bar deposition has resulted in lateral displacement (up to 15 m) of the stream channel in several areas of the reach. Mine tailings effects on water quality and macroinvertebrate abundance may be most important in the upper sections of Soda Butte Creek near the park boundary; data from recent studies (Jones et al. 1988-1991, Postfire Studies, this volume) indicate that water quality and macroinvertebrate communities in the downstream reaches of Soda Butte Creek are suitable for trout.

Annual variation in fish populations has differed among study areas of Soda Butte Creek. In the Footbridge section, estimated population size, PSD, and mean length of captured fish have generally increased since 1984. In 1991, however, estimated abundance and biomass were the smallest since 1988, but may have been affected by sampling conditions. Extremely turbid water and poor visibility (< 15 cm) in 1991 decreased our sampling efficiency and may have negatively biased abundance estimates. Because the length structure of the 1991 sample was similar to that of recent years (Figure 27), the negative bias may not be restricted to any particular size group.

Since the implementation of the 330-mm minimum-size regulation in Soda Butte Creek in 1987, annual harvest has been concentrated on the larger fish in the population. When estimated population abundance and length structure derived from the Footbridge section electrofishing data are expanded to the entire 12-km reach below Icebox Canyon, VAR data suggest that, since 1987, approximately half of the fish available for harvest (>330 mm TL) below Icebox Canyon have been creeled. A comparable estimate of annual harvest under the unrestricted size limit in effect between 1977 and 1986 was 220 trout ≥330 mm. Because there are only 2 years of electrofishing data for this period, few electrofishing-VAR comparisons can be made; however, the data suggest that, prior to 1987, harvest rates for trout longer than 330 mm were at least equal to those noted after 1986. Despite these current harvest levels, other data (population abundance and length structure) suggest that the trout population in the lower reaches of Soda Butte Creek has improved compared to its status in the 1970s and the 1980s.

In the reach above Icebox Canyon that was accidentally treated with rotenone in 1988, reestablishment of the trout population has been slower than below Icebox Canyon (Jones et al. 1991). Mean total length of captured fish, and estimated mean age of trout in the 1991 sample were slightly smaller than values for these parameters in the pretreatment sample from 1987. Workman (1981) considered a reestablishment of the original age structure as evidence of recovery of an affected population. Although the age data indicate a minor proportion of older (>age-4) cutthroat trout in the Icebox Canyon reach, the predominance of age-2 and age-3 trout and rapid growth rates observed in the past 3 years suggest that the this cutthroat trout population should resemble the pretreatment population within the next 2 years.

At the Northeast Boundary sample reach, trends in fish population characteristics have been variable, but the population has apparently increased since 1989. The scarcity of large (≥330 mm) trout in the electrofishing samples (Figure 26) remains a concern, however. Although VAR data suggest that the abundance of large trout has increased in the upper reaches of Soda Butte Creek in recent years, the current estimated harvest rates could result in most of these fish being creeled.

Electrofishing and VAR data suggest that Soda Butte Creek supports a high-quality native cutthroat trout fishery. Current data have attempted to describe the annual variation associated with this fishery. A complex variety of factors regulate the trout populations in this stream and isolating the influence of any particular factor may not be feasible. Consequently, continued monitoring of this fishery should include consideration of "natural variation" as well as human-induced impacts.

Although the 1991 data indicate an improvement in the trout population in the upper reaches of the stream, planned expansion of mining activities near Cooke City could affect water quality and macroinvertebrate abundance near the park boundary. In addition, an increase in angler effort and harvest of trout in Soda Butte Creek may accompany the additional personnel needed to operate new mine facilities. Continued examination of long-term fish population dynamics will assist in making the proper decisions to assure the viability of the self-sustaining population of wild trout in Soda Butte Creek.

FLUVIAL ARCTIC GRAYLING RESTORATION STUDIES

A primary fishery management objective in Yellowstone National Park is the perpetuation and restoration of native fish species. An important step in accomplishing this objective is determination of the distribution and status of indigenous populations. Fishery managers in Yellowstone National Park have had a particular interest in the fluvial (stream-dwelling) form of the Arctic grayling *Thymallus arcticus*. Within the Park, the historical distribution of the grayling included the Madison River drainage downstream from Gibbon Falls and Firehole Falls, the Grayling Creek drainage, and the Gallatin River (Smith and Kendall 1921). Although previous introductions of Arctic grayling into several lakes in the Gibbon River watershed produced viable populations, known fluvial populations have disappeared within park boundaries (Varley and Schullery 1983).

Recent concerns have been expressed about the decline in populations of fluvial Arctic grayling throughout its historical range within the contiguous United States (Baxter and Simon 1970; Williams et al. 1989; Kaya 1991). Presently, the only known fluvial grayling population resides in the Big Hole River, Montana. The decline of the fluvial grayling has led to two types of fishery management studies in Yellowstone Park. In recent years, reports of anglers catching grayling have prompted surveys in the Gibbon River to verify the presence of grayling. These surveys have also assessed survival among a group of 25,000 grayling fingerlings of Red Rocks Lake, MT, origin that were stocked into the Gibbon River in 1988.

The second type of study has involved surveys of streams within the historic grayling range that may be suitable for grayling reintroduction. In 1976, after a preliminary survey, Canyon Creek, a tributary of the Gibbon River, was selected as a reintroduction site. Grayling restoration attempts in Canyon Creek were unsuccessful, however (Jones et al. 1977-1982). Varley et al. (1976) suggested that streams devoid of exotic salmonids should be considered as potential grayling reintroduction sites. Because Cougar Creek is physically isolated from adjacent streams and contains only native fish species, it is a promising stream for reintroduction of fluvial Arctic grayling.

In 1991, the Gibbon River was surveyed in response to angler reports of grayling being caught near Madison Junction. In addition, a comprehensive baseline survey was conducted on Cougar Creek, a stream being considered for grayling restoration.

Study Areas

The Gibbon River was surveyed from Tuff Cliffs picnic area downstream for 9.2 km to the confluence with the Madison River.

The two upstream reaches, bordered by a forested riparian area, were 1.3 km (Section 1) and 1.9 km long (Section 2) and contained abundant downed timber within the stream channel. The downstream reaches were 2.1 km (Section 3) and 3.9 km (Section 4) in length (Figure 33), were located in a meadow, and had an average gradient (0.1%) approximately half that of the upstream reaches. In these meadow sections, deep pools were common and substrate was predominately gravel and sand.

Cougar Creek is located approximately 5 km north of the Madison River within a 5,700-ha drainage basin (Figure 34). Topography of the Cougar Creek headwaters is a result of extensive welded ash flows (Lava Creek Tuff) during Pleistocene volcanism. The southeastern areas of the drainage are primarily colluvial deposits that reveal little evidence of Pleistocene glaciation (Waldrop and Pierce 1975), but other upland areas are covered with Bull Lake glacial till or Pinedale rubble veneer. From the steep headwater reaches, Cougar Creek flows westerly for 22 km and subsides underground in the eastern section of the Madison Valley. The upper reaches of the stream are enclosed by steep-walled canyons covered with dense stands of mature lodgepole pine *Pinus contorta*.

Below an elevation of 2,075 m, Cougar Creek flows through nonforested meadows in a wide valley covered by unconsolidated glacio-fluvial deposits (Christiansen and Blank 1974). The broad low-gradient areas where Cougar Creek flows underground are alluvial deposits of fine particles. A National Park Service patrol cabin is located near the stream approximately 9 km upstream from the terminus of Cougar Creek.

The only salmonid known to occur in Cougar Creek is westslope cutthroat trout *Onchorhynchus clarki lewisi*. (Although these cutthroat were believed to be genetically pure [Loudenslager and Gall 1981], recent electrophoretic evidence suggests some introgression with Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* [D. Shiozawa, personal communication]). Introgressed populations of westslope cutthroat exist in the Gallatin River drainage (Jones et al. 1984) and in Grayling Creek (R. Leary, unpublished data), but the population in Cougar Creek appears to be the most genetically pure within Yellowstone National Park. Although their precise genetic status is presently unknown, the trout of Cougar Creek are considered to be westslope cutthroat trout in the present discussion.

An initial survey of Cougar Creek was conducted in 1978, when a single study site was selected near the patrol cabin. Detailed physical, chemical, and biological results were presented in Jones et al. (1979). In the 1991 survey, each of the four study sections in Cougar Creek was 152 m long. Reaches 1 and 2 were downstream from the patrol cabin in a meadow area that was extensively burned during the 1988 forest fires. In

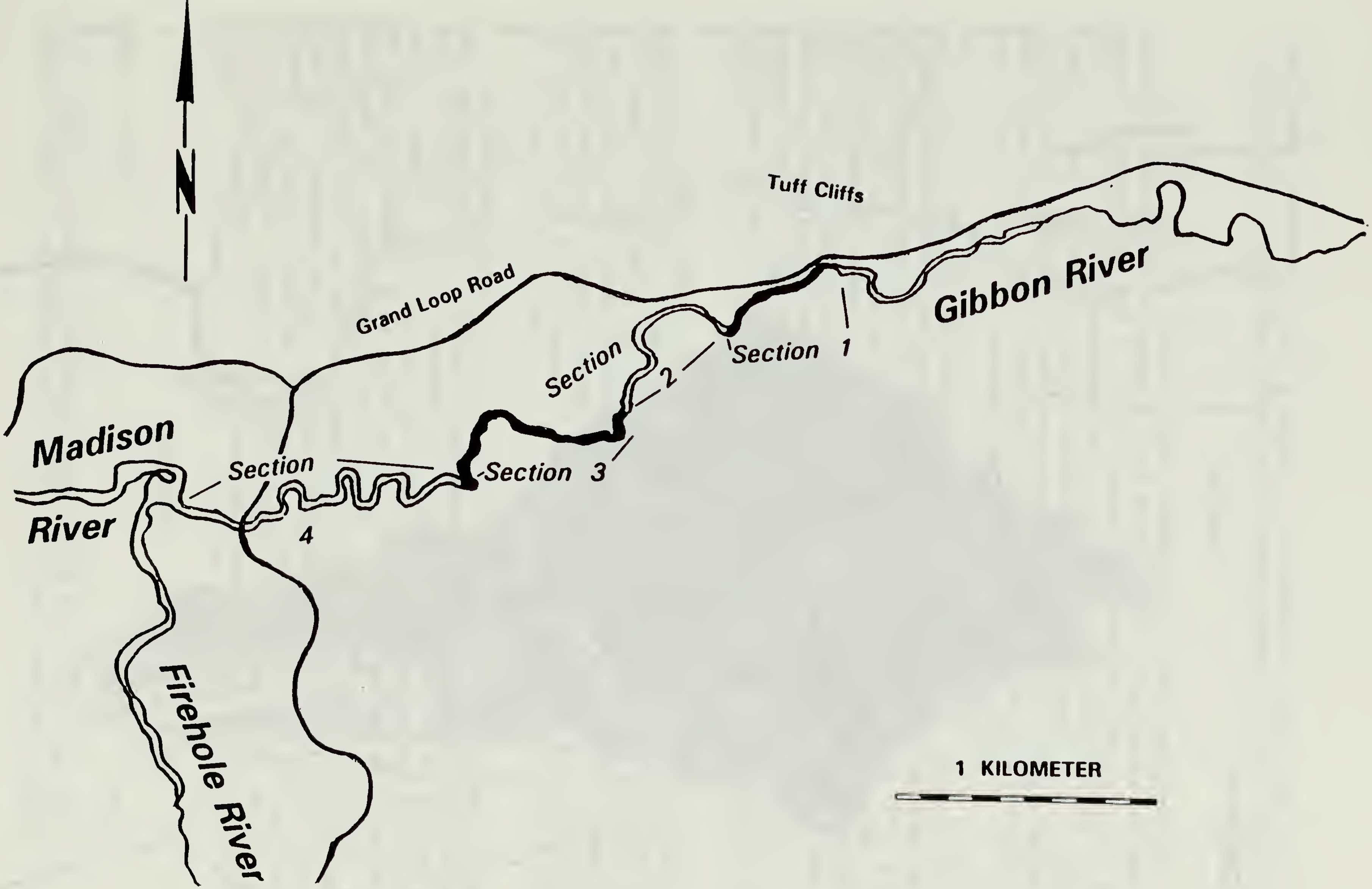

FIGURE 33.-Electrofishing reaches in Tuff Cliff area of Gibbon River, 1991.

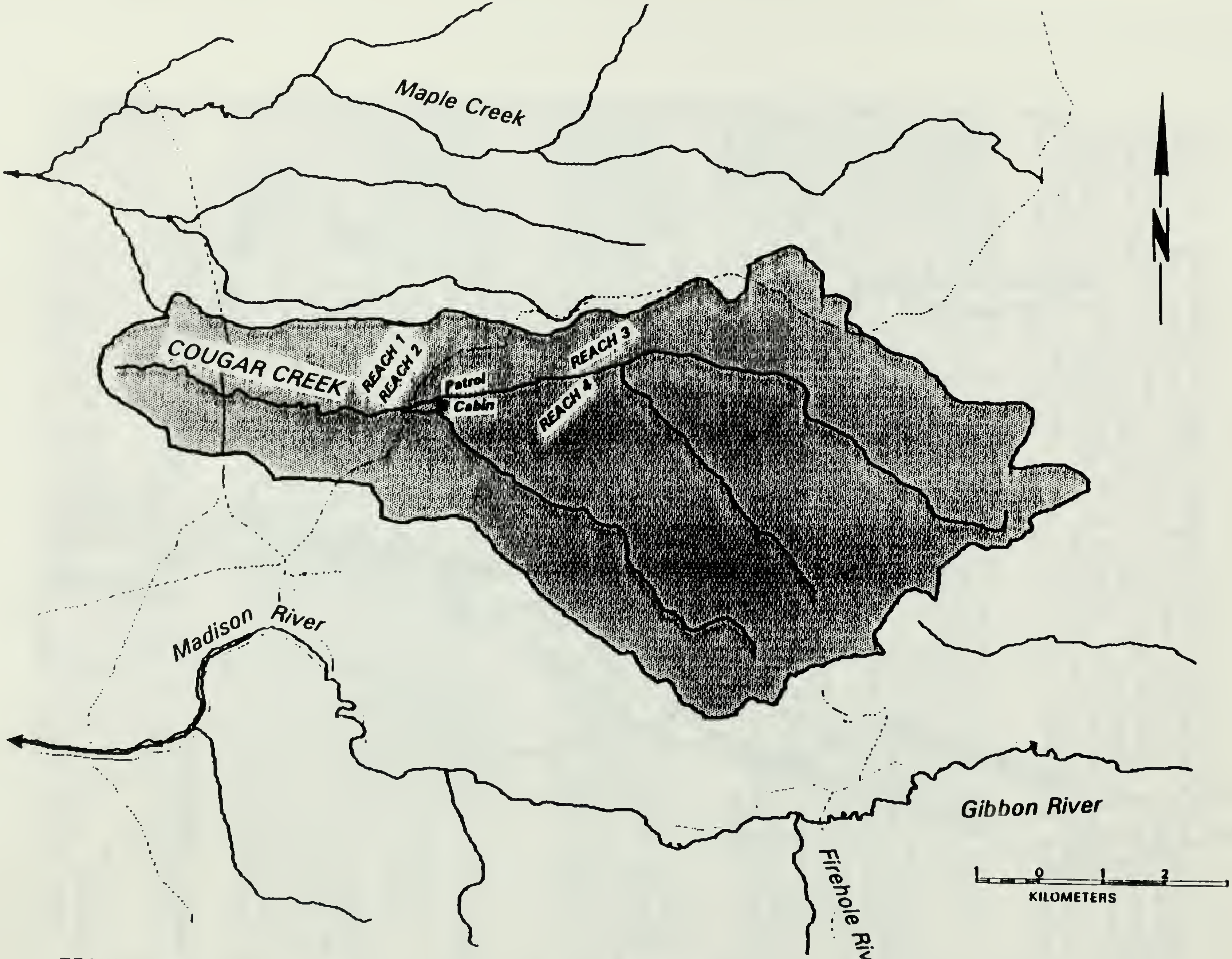

FIGURE 34.-Electrofishing and habitat study reaches in Cougar Creek, 1991.

contrast, Reaches 3 and 4 were 2 km upstream from the cabin in a forested area that was relatively unaffected by the 1988 fires.

Methods

In the Gibbon River, data acquisition was restricted to quantification of standard fish population characteristics. Fish were captured during a single pass of electrofishing from a 4-m raft. All fish were measured to the nearest millimeter total length, and salmonids were weighed to the nearest 2 g. One-way analysis of variance and Newman-Keuls multiple means comparison test (Zar 1984) were used to detect significant differences in mean total length of salmonids among study sections.

Data from the Volunteer Angler Report (VAR) system from 1979 to 1991 were examined to detect trends in angler success in catching grayling in the Gibbon and Madison rivers. For purposes of VAR analyses, the Gibbon River has traditionally been subdivided into several reaches. The sections encompassing the 1991 electrofishing area and an adjacent reach upstream are the Madison Junction section and the Gibbon Meadows section, respectively. The Madison River has been subdivided into Above (upstream from) 7-Mile Bridge and Below (downstream from) 7-Mile Bridge.

In Cougar Creek, fish were captured with a Coffelt BP-1 backpack shocker. A multiple-pass removal method (Zippin 1958) was used to collect the fish. Population size was estimated with a maximum-likelihood formula (White et al. 1982). For age-growth determinations, scales were collected from trout in a subsample of the catch. Other population data were collected and analyzed as in the Gibbon River.

In each study reach of Cougar Creek, three habitat transects were established. Stream discharge was measured at one transect in each reach by the midsection method (Buchanan and Somers 1969). Additional habitat parameters were estimated based on methods described in Platts et al. (1983). Water samples were analyzed by a commercial laboratory. In each reach, three macroinvertebrate samples were obtained with a 0.09 m^2 Surber sampler. Subsequently, macroinvertebrates were assigned to trophic groups based on the classification of Merritt and Cummins (1984). Biotic Condition Index (BCI) for each reach was calculated according to techniques described in Winget and Mangum (1979).

Results

Gibbon River

Fish.-In 1991, one Arctic grayling was captured in the Gibbon River near Madison Junction. Total length, weight, and condition factor (K) of the grayling was 267 mm, 144 g, and 0.76, respectively. Brown trout *Salmo trutta* was the most frequently captured (37%) species, followed by rainbow trout *Oncorhynchus mykiss* (36%), and mountain whitefish *Prosopium williamsoni* (27%) (Table 18). Several longnose dace *Rhinichthys cataractae*, mountain suckers *Catostomus platyrhynchus*, and mottled sculpins *Cottus bairdi* were also collected.

In the forested reach (Sections 1 and 2), significantly more brown trout were captured than rainbow trout or whitefish (χ^2 = 6.80, P = 0.03). These results appear related to the relatively high number of brown trout captured in Reach 2; whether the difference in numbers of brown trout captured is due to varying electrofishing efficiencies, an undetected change in habitat (e.g., gradient), or an unknown factor cannot be determined from the available data. No significant interspecific differences in abundance were detected in the meadow reach (sections 3 and 4). In addition, there were no significant differences in the number of brown trout or rainbow trout captured in the two habitat types, but significantly more whitefish were captured in the non-forested reaches than in the forested reach (χ^2 = 4.31, P = 0.04). There were no differences in relative abundance (number of fish/km) among species in either the forested or nonforested sections.

Whitefish were generally the longest fish captured in each section (Table 18) and ranged from 111 to 445 mm total length (mean, 351 mm). Brown trout total length ranged from 71 to 477 mm in length (mean, 253 mm). Comparison of mean lengths of salmonids from the four shocking sections revealed no significant differences (P > 0.05), suggesting that length groups for each species were similar throughout the entire study area.

Anglers.-Data from the VAR system have shown a declining trend in the reported number of grayling landed in the Gibbon River since a high was reached in 1981 (Figure 35). Varley and Schullery (1983) suggested that grayling caught in the Gibbon River or Madison River were downstream migrants from Wolf Lake and Grebe Lake. Although VAR data that indicate grayling were caught throughout the Gibbon River between 1979 and 1985 might support this migration theory, the increase and subsequent decline in grayling landings that occured between 1979 and 1985 might also be related to the stocking of grayling in Canyon Creek, which occurred between 1976 and 1980 (Jones et al. 1977-1981). Since 1985 reported landings of grayling have been primarily from the lower reaches of the river (e.g., Gibbon Meadows and Madison Junction sections). In the Madison River, trends in the number of grayling caught are less apparent (Figure 36). Prior to 1988, most of the reported grayling landings were downstream from 7-Mile Bridge; since 1988, however, most of the grayling have been caught between Madison Junction and 7-Mile Bridge.

TABLE 18.-Population characteristics of fishes captured by electrofishing in the Gibbon River, 1991.

	Grayling	Rainbow Trout	Brown Trout	Mountain Whitefish	Longnose dace	Mountain sucker	Mottled sculpin
Section 1							
N	0	10	8	10	2	1	1
Mean length (mm)	--	245	259	360	95	185	65
Mean weight (g)	--	166	210	--	--	--	--
Mean K	--	1.03	1.05	--	--	--	--
Section 2							
N	0	9	29	11	3	2	1
Mean length (mm)	--	258	310	362	87	171	60
Mean weight (g)	--	185	329	436	--	--	--
Mean K	--	1.01	0.98	0.89	--	--	--
Section 3							
N	0	21	12	9	0	2	0
Mean length (mm)	--	258	316	294	--	149	--
Mean weight (g)	--	199	260	311	--	--	--
Mean K	--	0.96	1.02	0.88	--	--	--
Section 4							
N	1	41	35	32	11	0	1
Mean length	267	251	281	361	75	--	35
Mean weigth (g)	144	209	287	400	--	--	--
Mean K	0.76	0.97	1.01	0.95	--	--	--

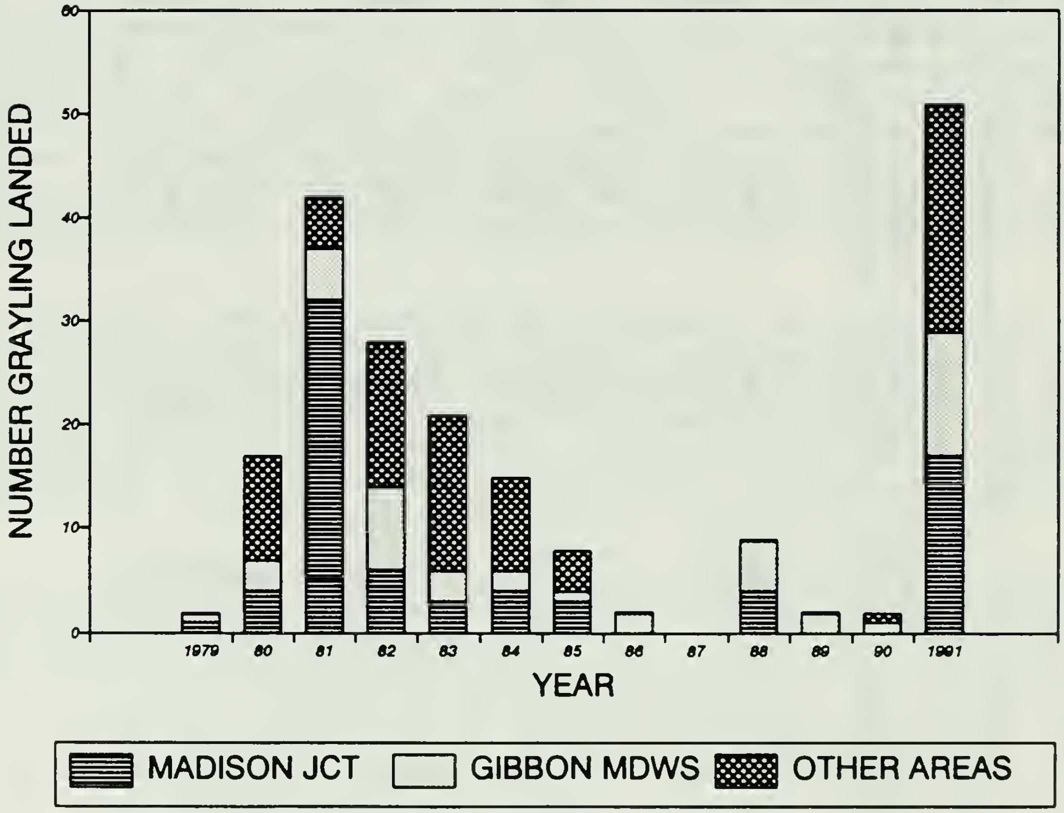

FIGURE 35.-Number of grayling reported caught by anglers in three sections of the Gibbon River. Data derived from Volunteer Angler Reports, 1979-1991.

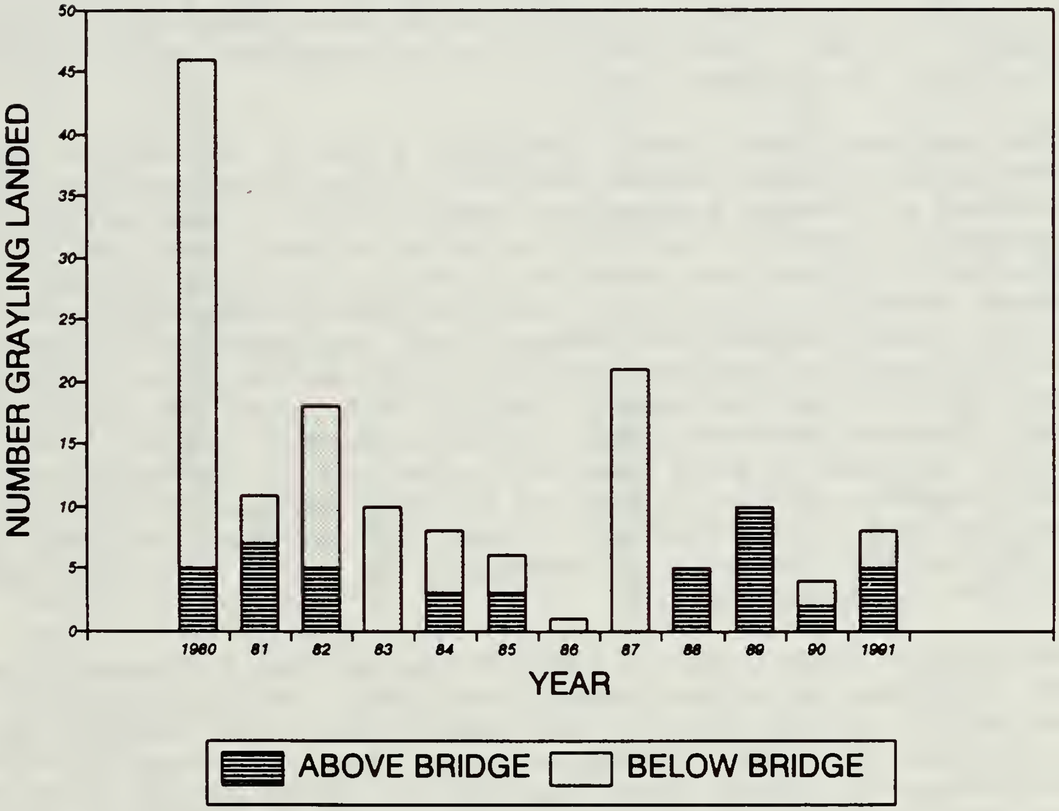

FIGURE 36.-Number of Arctic grayling reported caught by anglers in two sections of the Madison River. Data derived from Volunteer Angler Reports, 1980-1991.

Cougar Creek

Physical characteristics.-The four study sections in Cougar Creek had similar gradient, stream width, pool-forming features, and riparian streambank habitat type (Table 19). Stream depth averaged 27 cm in the meadow sections in the lower-elevation portion of the watershed (Reaches 1 and 2). In these reaches, pools were less than 1 m wide and were rated low quality, primarily because suitable cover for fish was lacking. Streambank vegetative stability was rated high, and less than one-quarter of the streambanks were eroded. Although gravel was the predominant size class in the substrate, sand or silt represented nearly one-third of the substrate in these two reaches (Table 19). Instream vegetation cover was limited in the meadow reaches; however, overhanging grassy banks averaged almost 50 cm in width. In conjunction with the deep undercuts (mean shore depth, 16 cm), the vegetated banks appeared to be the best cover for fish in Reaches 1 and 2.

The upstream study areas (Reaches 3 and 4) of Cougar Creek were shallower but had larger pools than the downstream sections. An abundance of downed timber and other channel vegetative cover was a primary factor in rating the pools as good-to-high quality. Streambank alteration was greater in these upstream reaches and vegetation stability was lower than the meadow area reaches (Table 19). High streambank instability may partially account for the observation that the average width of undercut banks in the upstream reaches was nearly double that noted in the meadow sections. Bottom substrate was almost entirely gravel, and measurable amounts of silt were not observed at the transects in the upper reaches (Table 19). The primary streambank habitat type was sod and fine materials (type 13); however, average width of the vegetation overhang in Reaches 3 an 4 was only half that noted in the lower reaches.

Chemical characteristics.-Water chemistry of Cougar Creek has been analyzed on three dates since 1978. Bicarbonate was the dominant anion in all samples and concentration of calcium and sodium ions was similar in each sample. The water-type classification of Cougar Creek has varied among sample dates in response to fluctuations in the calcium-sodium milliequivalent ratio (Table 20).

Total dissolved solids concentration (TDS) has ranged from 44 to 75 mg/L and is low compared to a mean of 113 mg/L from almost 300 water samples taken from streams throughout Yellowstone National Park. The maximum TDS value recorded in Cougar Creek was 25% less than the average for calcium-carbonate streams in the park (101 mg/L). Concentrations of 50 mg/L TDS ranked Cougar Creek low among sodium-bicarbonate streams. Total alkalinity values reflect the dilute condition of Cougar Creek, which is in the 10th percentile of park streams of either water type. Because total alkalinity is correlated with

TABLE 19.-Drainage basin characteristics and habitat features of Cougar Creek, 1991. All values (except streamflow) are means for three transects.

	Reach			
Habitat features	#1	#2	#3	#4
Sample date	8/27	8/27	8/28	8/28
Time	1710	1830	1320	1530
Water column:				
Flow (m^3/s)	0.212	0.230	0.100	0.141
Channel width (m)	4.20	4.45	4.09	4.24
Stream width (m)	2.32	2.17	2.62	2.11
Stream depth (cm)	27	27	15	18
Stream shore water depth (cm)	18	14	10	7
Riffle width (m)	0.99	1.79	1.63	1.60
Pools:				
Width (m)	0.80	0.29	1.00	0.52
Quality	2.0	1.34	3.5	2.67
Feature[a]	2	2	1,2	1
Solar angle (°)	126	148	149	140
Channel morphology				
Streambank alteration (%)	22.5	22.5	23.3	35.8
Vegetative stability	3.67	3.5	3.17	3.0
Undercut (cm)	7	11	20	8
Channel-bank angle (°)	106	68	70	128
Stream bottom:				
Gradient (%)	0.5	0.5	0.5	0.7
Sinuosity	1.51	1.15	1.41	1.28
Substrate: (%)				
Boulder (>305 mm)	0	15.1	0	0
Cobble (64-305 mm)	0	0	0	0
Gravel (2-64 mm)	59.5	53.1	87.7	80.1
Sand (0.6-2 mm)	18.6	31.8	12.3	19.9
Silt (<0.6 mm)	21.9	0	0	0
Embeddedness (%)	100	100	100	100
Channel vegetative cover (cm)	17	0	35	48
Riparian zone:				
Streamside cover type	2.0	2.0	2.0	2.0
Vegetative use (%)	29.2	14.2	9.2	11.7
Vegetation overhang (cm)	50	50	22	18
Habitat type	13	13	13	13,18

---

[a] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

TABLE 20.-Results of chemical analysis of water samples taken from Reach 2 of Cougar Creek, 1978, 1981, and 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

	Cougar Creek		
DATE	9/08/78	7/10/81	8/29/91
STREAM TYPE	NA + K-HCO_3	CA-HCO_3	NA + K-HCO_3
TDS	50.00	75.00	44.00
CONDUCTIVITY	75.00	70.00	65.00
pH	7.20	7.20	7.91
P ALKALINITY	0.00	0.00	1.90
T ALKALINITY	18.00	16.00	24.30
CO_3	0.00	0.00	1.90
HCO_3	22.00	20.00	24.30
CL	1.40	0.90	0.90
SO_4	2.00	2.20	1.73
FL	2.50	2.90	1.66
COLOR	0.00	0.00	4.90
TURBIDITY	1.30	4.30	2.80
T HARDNESS	12.00	21.00	21.00
CA HARDNESS	10.00	20.00	16.00
CA	4.00	8.00	6.60
MG	0.50	0.20	1.20
NA	6.60	8.20	7.20
FE	0.02	0.01	0.15
MN	0.05	0.05	0.03
CU	0.09	0.19	0.01
SI	24.00	17.00	30.80
K	1.00	1.00	1.10
WATER TEMP	11.10	7.80	13.30

macroinvertebrate productivity (e.g., Mangum 1986b), these results suggest that primary productivity in Cougar Creek could be limited. Low (<50 mg/L) total hardness indicates Cougar Creek is a "soft" water (Hem 1985).

Silica was one of the few elements from Cougar Creek that exhibited an elevated concentration (parkwide mean, 16 mg/L). Cougar Creek ranked 31 of 91 sodium-bicarbonate waters tested and was in the 75th percentile of calcium-carbonate waters tested. Hem (1985) observed that streams in rhyolitic drainages often contain high silica concentrations.

Aquatic macroinvertebrates.-Twenty-four macroinvertebrate taxa were collected from Cougar Creek in 1991, six Diptera and five each of Ephemeroptera, Plecoptera, and Trichoptera (Table 21). Species richness (number of taxa collected) was similar among study reaches. Although relative abundance (number of individuals/m^2) varied considerably among reaches, there was no significant difference between the meadow areas (Reaches 1 and 2) and the forested sections (Reaches 3 and 4) (paired t-test, $P = 0.51$). Shannon-Wiener diversity index was nearly identical among three of the four reaches in Cougar Creek (Table 21).

Chironomids were the most abundant macroinvertebrates sampled and reached an estimated density of 3600 individuals/m^2 in Reach 3. Chloroperlid stoneflies were also numerous but generally declined in abundance in an upstream direction (Table 21). *Cleptelmis ornata* (Elmidae) and *Hexatoma* sp. (Tipulidae) were also found in each reach. Ephemeropterans were more abundant in the meadow sections than in the forested reaches; however, Trichopteran distribution exhibited the opposite pattern.

Functional feeding group classification (Vannote et al. 1980) revealed that predators were the most abundant trophic group in each reach of Cougar Creek in 1991. The predator group was composed primarily of Chloroperlid stoneflies, Perlodid stoneflies, and Tipulidae. Gathering collectors (particularly chironomids) represented most of the remaining macroinvertebrates. Chironomids are a common prey for Chloroperlid stoneflies (G. Roemhild, personal communication) and the predominance of predators in Cougar Creek may be attributed to a substantial chironomid prey base. In contrast, the scarcity of scrapers in this stream suggests limited production of instream vegetation.

Biotic Condition Indices (BCI) greater than 85 are indicative of high-quality macroinvertebrate habitat (Winget and Mangum 1979). Values for BCI in Cougar Creek range from 101 to 129 and suggest excellent macroinvertebrate habitat. The collection of several environmentally sensitive species (e.g., TABLE 21-.Abundance, diversity, community trophic structure, and Biotic Condition Index (BCI) for benthic macroinvertebrates collected from Cougar Creek, 1991. Number of taxa is a pooled result from each reach. Other values are means of three samples from each reach.

	Reach 1	Reach 2	Reach 3	Reach 4
Ostracoda (seed shrimps)		18	362(b)	
Insecta				
Ephemeroptera (mayflies)				
Baetidae				
Baetis bicaudatus	111	11	14	
Heptageniidae				
Cinygmula sp.	4			
Ephemerellidae				
Drunella doddsi			4	
Drunella grandis	14	7		4
Ephemerella infrequens	7	4		
Plecoptera (stoneflies)				
Taeniopterygidae				
Taenionema sp.	4	18		
Perlidae				
Hesperoperla pacifica	4		4	
Perlodidae	373		14	11
Chloroperlidae(a)	373	205	104	133
Kathroperla perdita				4
Hemiptera				
Gerridae				
Gerris sp.		4		
Trichoptera (caddisflies)				
Rhyacophilidae				
Rhyacophila sp.	4			4
Brachycentridae				
Amiocentrus sp.		4		
Brachycentrus sp.			22	7
Micrasema sp.	4			4
Limnephilidae				
Apatania sp.	4			7

TABLE 21.-Continued

	Reach 1	Reach 2	Reach 3	Reach 4
Coleoptera (beetles)				
Elmidae				
Cleptelmis ornata	32	4	4	18
Diptera (true flies)				
Tipulidae				
Hexatoma sp.	7	7	7	4
Pedicia sp.			11	4
Simulidae				
Prosimulium sp.				11
Chironomidae(a)	57	32	3600(b)	39
Athericidae				
Atherix pachypus		4	50	
Empididae	11			
TOTAL TAXA:	15	12	12	13
TOTAL #/m^2	1008	316	4194	248
STANDARD ERROR	(348)	(124)	(3947)	(139)
DIVERSITY INDEX	1.52	1.53	1.52	2.00
STANDARD ERROR	(0.26)	(0.12)	(0.50)	(0.18)
BCI	129	101	125	115
STANDARD ERROR	(9)	(6)	(27)	(10)
% SHREDDERS	0.8	3.7	0	2.1
STANDARD ERROR	(0.8)	(3.7)	N/A	(2.1)
% COLLECTORS	19.2	21.2	47.0	29.5
STANDARD ERROR	(9.9)	(0.8)	(23.6)	(6.0)
% SCRAPERS	1.1	18.5	0	1.4
STANDARD ERROR	(0.3)	(18.5)	N/A	(1.4)
% PREDATORS	78.9	56.6	53.0	67.0
STANDARD ERROR	(10.6)	(22.8)	(23.6)	(7.8)

a) - identified to family level
b) - minimum estimate

Drunella doddsi, Hesperoperla pacifica, and *Rhyacophila* sp.) also suggests that Cougar Creek is high-quality macroinvertebrate habitat.

Fish.-More than 100 cutthroat trout were captured by electrofishing in Cougar Creek in 1991. Number of captured trout was similar among the four reaches, but population size could be reliably estimated in only 3 of the 4 study sections (Table 22). An erratic capture pattern in Reach 3 yielded extremely wide confidence limits and a population that is probably substantially overestimated.

Mean total length (TL) of cutthroat was greatest in Reach 1 and declined in the upstream reaches (Table 22); however, these differences were not statistically significant ($F = 2.13$, $P = 0.10$). Approximately half of the captured trout in each reach were longer than 150 mm TL (Figure 37). The length-frequency distribution of the combined population from all study sections followed a similar pattern (Figure 38).

Mean weight of cutthroat trout in the meadow sections was more than twice that of trout captured in the forested reaches (Table 22). Consequently, estimated biomass in the upper reaches was only half that of the lower sections. Condition factor (K) of captured trout was similar among the stream survey sections.

Scale analysis revealed a minimum of five age classes of cutthroat trout in Cougar Creek. Average estimated age of captured cutthroat trout was 1.8 years. Based on back-calculated lengths at each annulus, two trout in the lower reaches of Cougar Creek were estimated to be 4 or 5 five years old. Estimated mean age paralleled the pattern observed for total lengths and decreased in an upstream direction from 2.2 years in Reach 1 to 1.7 years in Reach 4. Growth rates of cutthroat trout were similar throughout Cougar Creek and averaged about 60 mm/year.

In addition to cutthroat trout, 175 mottled sculpins *Cottus bairdi* were captured. Significantly fewer sculpins were captured in the meadow reaches than in the forest reaches ($\chi^2 = 7.34$, $P < 0.01$). As with cutthroat trout, reliable population estimates could be made in all areas except Reach 3.

Mean total length of mottled sculpins was similar ($P > 0.05$) among reaches (Table 23); however, the broadest range in length and the largest individual (133 mm TL) were found in the upper reaches. Estimated mean weight of sculpins was similar among reaches. Estimated biomass of sculpins in Reaches 1 and 2 was 10% that of cutthroat trout.

In 1991, the length-frequency distribution of the cutthroat trout population was similar among Cougar Creek study reaches.

TABLE 22.-Population characteristics of cutthroat trout captured from Cougar Creek, 1991.

	Reach 1	Reach 2	Reach 3	Reach 4
Number captured (*N*)	21	29	35	29
Population estimate	25	31	96	31
95% confidence interval	21-35	29-36	35-305	29-36
Mean length (mm)	175	161	142	140
Mean weight (g)	88	79	35	39
Condition factor (K)	1.06	0.95	0.96	0.99

TABLE 23.-Population characteristics of mottled sculpins captured from Cougar Creek, 1991.

	Reach 1	Reach 2	Reach 3	Reach 4
Number captured (*N*)	22	41	63	49
Population estimate	28	58	1572	63
95% confidence interval	22-42	41-88	63-35778	49-85
Mean length (mm)	77	72	73	74
Mean weight (g)	6	5	6	6
Condition factor (K)	1.15	1.06	1.28	1.26

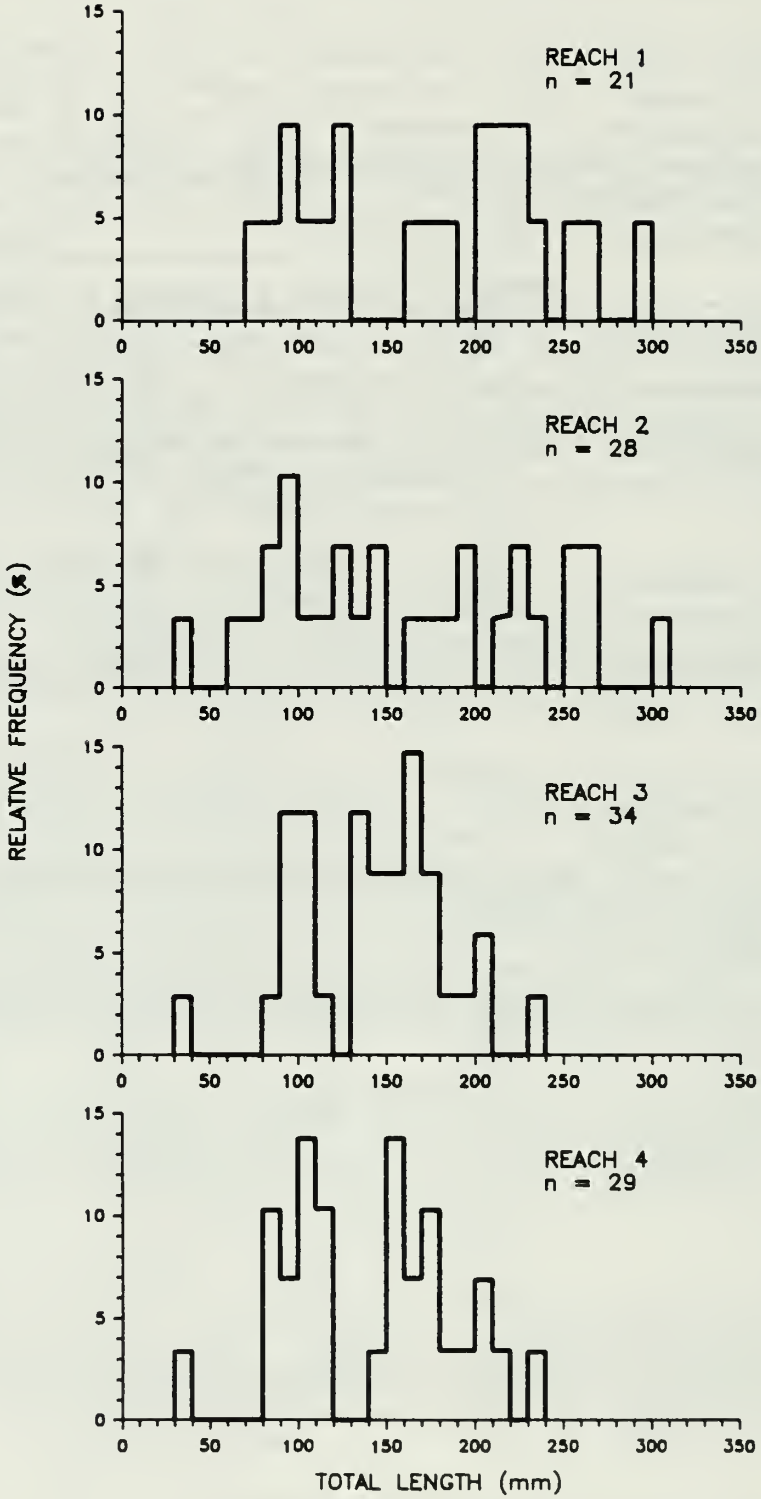

FIGURE 37.-Length-frequency of cutthroat trout captured by electrofishing, Cougar Creek, 1991 (reaches 1-4).

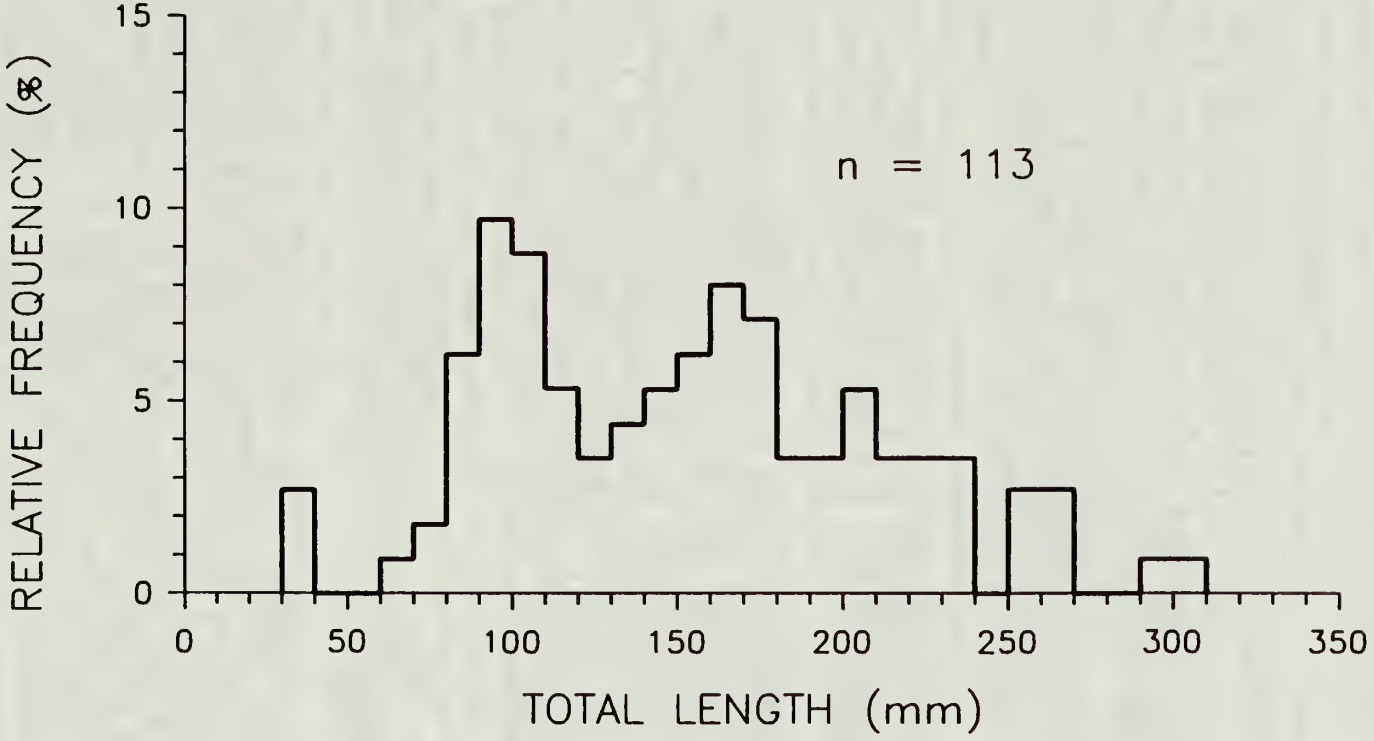

FIGURE 38.-Length-frequency of cutthroat trout captured in Cougar Creek, 1991, all sections combined.

There were an estimated 90 to 100 cutthroat trout longer than 150 mm TL per kilometer of stream. Estimates for this size range in the 1978 study were approximately 55 trout/km (Jones et al. 1979). In contrast with the earlier survey, sculpin biomass estimates in the 1991 survey were considerably smaller than cutthroat trout biomass.

Discussion

The decline of fluvial Arctic grayling throughout its historic range in the contiguous United States necessitates efforts to restore this native fish species. The apparent elimination of fluvial grayling from Yellowstone National Park has been attributed to establishment of nonnative fishes and excessive angler harvest (Varley et al. 1976). Since 1988, when 25,000 fingerling grayling from Red Rocks Lake, MT, were stocked in the Gibbon River, our electrofishing efforts have yielded only two grayling (Jones et al. 1989-1991; present study). Although it is unknown whether these captured grayling were from the 1988 Red Rocks Lake stock, downstream migrants from Grebe Lake or Wolf Lake, or remnants of a fluvial population, these results indicate that grayling are a minor component of the Gibbon River fish community.

Several million grayling were stocked in the Gibbon and Madison rivers during the first half of this century (Varley 1981), but did not establish resident populations. Kaya (1991) demonstrated that juvenile fluvial grayling tend to maintain their position within a stream, whereas lacustrine (lake-dwelling) grayling migrate downstream shortly after emergence from the gravel. Stocking records (Varley 1981) indicate that the grayling stocked into the Gibbon River and the Madison River were lacustrine forms. The apparent failure to establish fluvial populations within Yellowstone National Park suggests that the source of potential donor stocks may be as important as other factors (e.g., competition with nonnative salmonids) that affect survival of fluvial grayling in the Gibbon and Madison River watersheds.

In contrast with the effects of nonnative fish on fluvial grayling, angler harvest of grayling has been considerably reduced since catch-and-release regulations for grayling were instituted in 1970. In the Madison Junction section of the Gibbon River and downstream in the Madison River, relatively high numbers of grayling were reportedly caught several years after the 1978-1980 restoration efforts in Canyon Creek and the 1988 stocking in Gibbon River (Figures 35 and 36). Estimated lengths of the angler-caught grayling in 1981 and 1991 are consistent with average lengths given by Brown (1971) for 2-4-yr-old grayling. This suggests that some of the grayling from earlier stocking efforts have survived in the lower reaches of the Gibbon River and the Madison River. Whether the grayling caught between 1980 and 1991 are downstream migrants from Canyon Creek, from the headwater reaches of the Gibbon River, or represent remnants of a fluvial population is unknown. Nevertheless, verification of the presence of Arctic grayling in the Gibbon River in both 1990 (Jones et al. 1991) and 1991 (present study), as well as the increase in reported landings of grayling in the Gibbon River and upstream portions of the Madison River in 1991, are encouraging results. Despite uncertainty in the origin of the landed grayling, these data underscore the need for continued protection of the grayling populations through angling restrictions and public education. Continued monitoring will allow for additional examination of annual variation in this fishery.

Angler use in Cougar Creek appears to be negligible (Jones et al. 1979), possibly due to the small size of the resident cutthroat trout (R. Danno, personal communication) and backcountry location of the stream. It is anticipated that angler impacts on the proposed grayling reintroduction would be minimal because the grayling would be protected by the catch-and-release regulation.

Generally, preferred grayling habitat consists of large, cold rivers with numerous deep pools (Scott and Crossman 1973). Although Cougar Creek is not a large stream, it may be suitable grayling habitat because several large pools deeper than 1 m occur within the survey area. Temperature data from Cougar Creek are limited and recorded temperatures may be near the seasonal maximum because they were collected during mid- to late summer in all years (Table 20). These temperatures may be within preferred ranges for grayling and are lower than those of geothermally influenced streams (e.g., Madison River) that historically supported fluvial grayling. Water chemistry results suggest limited productivity in Cougar Creek; TDS concentrations were only 25% to 50% of nearby coldwater streams within the historic grayling range.

Relative abundance and species richness of macroinvertebrates were similar between the 1978 and 1991 samples. Nearly all of the taxa collected by Surber sample and more than 60% of the species collected by drift net in 1978 (Jones et al. 1979) were collected in 1991. Jones et al. (1979) stated that "low invertebrate productivity" was a major factor contributing to the small size of cutthroat trout in Cougar Creek. Our data on macroinvertebrate abundance could lead to a similar conclusion; however, the presence of a large percentage of predators suggests that macroinvertebrate abundance was near a seasonal low during the sampling period in 1991. Generally, in late-summer macroinvertebrate collections, many of the non-predatory species have emerged as adults and the individuals that remain are small and uncommon (G. Roemhild, personal communication).

A grayling introduction into Cougar Creek could lead to competitive interactions (e.g., habitat selection or food availability) between grayling and cutthroat trout. Whether the introduction of fluvial grayling would negatively impact the current level of macroinvertebrate production in Cougar Creek is unknown. Westslope cutthroat trout and Arctic grayling coevolved, however, and could have differing food preferences that reduce competition for food. Brown (1971) stated that grayling have a diet similar to other trout, but Baxter and Simon (1970) and Scott and Crossman (1973) noted that terrestrial insects were more important in the diet of grayling than in other salmonids. During the 1991 survey, we observed numerous terrestrial insects (particularly Orthoptera) in the Cougar Creek riparian areas. Terrestrial insects that fall into the stream could be an important food source for grayling introduced into Cougar Creek.

The proposed introduction of fluvial grayling into Cougar Creek provides an opportunity to study the interaction of native fish species within their historic range. The available data from Cougar Creek provide a baseline from which these interactions can be monitored. The negative impacts from nonnative fish species and angler harvest that may have led to the elimination of fluvial grayling throughout most of its historic range do not occur in Cougar Creek. Physical, chemical, and biological characteristics indicate that Cougar Creek is suitable for introduction of fluvial Arctic grayling.

HISTORY OF FISHERY MANAGEMENT OF THE FIREHOLE RIVER

The Firehole River was historically barren of fish over most of its length (Jordan 1891). Between 1889 and 1955, repeated introductions of several native and nonnative salmonid species were made to the Firehole River and its tributaries (Varley 1981). The major sport fishery that developed in the Firehole River continued to be supported by stocking until 1955, when establishing and maintaining self-sustaining fish populations became a policy of the National Park Service. Today, the Firehole River has a nationally recognized sport fishery for brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* (Benson et al. 1959; Jones et al. 1989). Objectives of this report are to describe and assess changes in the sport fishery and fish populations of the Firehole River since the mid-1950s in relation to angling regulations, other management actions, and environmental variables, and to recommend future fishery management activities.

Study Area

The Firehole River drainage encompasses about 720 km² in west-central Yellowstone National Park. Most of the drainage is underlain by rhyolite, and glacial and surficial deposits therein are derived primarily from this volcanic rock (Meyer 1987). Vegetation is dominated by lodgepole pine *Pinus contorta*, grasses, and sedges. Wildfire affected about 38 percent of the Firehole River drainage in 1988 (Geographic Information Systems Laboratory, Yellowstone National Park, unpublished data).

The Firehole River originates near Madison Lake (elevation, 2,550 m) and flows north for about 44 km before joining the Gibbon River to form the Madison River at Madison Junction (elevation, 2,070 m; Figure 39). Mean-monthly discharge of the Firehole River ranges between 8 and 10 m³/s most of the year but may reach 13 to 14 m³/s during runoff in May and June (U.S. Geological Survey [USGS], 1984-1990). Average gradient of the Firehole River is 1.1 percent.

The Firehole River is a coldwater stream from its headwaters to about 3 km below Kepler Cascades (Argyle 1966; Burkhalter 1979). Downstream from that location water temperatures are elevated by additions of geothermally heated waters from hot springs and geysers in the Upper, Midway, and Lower geyser basins. During the seasonal low-flow period, such geothermal effluents constitute 20 to 40 percent of the discharge of the Firehole River (Burkhalter 1979). Approximate mean-annual temperature of the Firehole River is 6°C upstream from Kepler Cascades, 15°C at Biscuit Basin, 18°C in the Lower Geyser Basin, 14°C about 3 km downstream, and 14°C at the USGS gaging station near Firehole Falls (Kaeding 1976; USGS, 1984-1990; U.S. Fish and Wildlife Service, unpublished data).

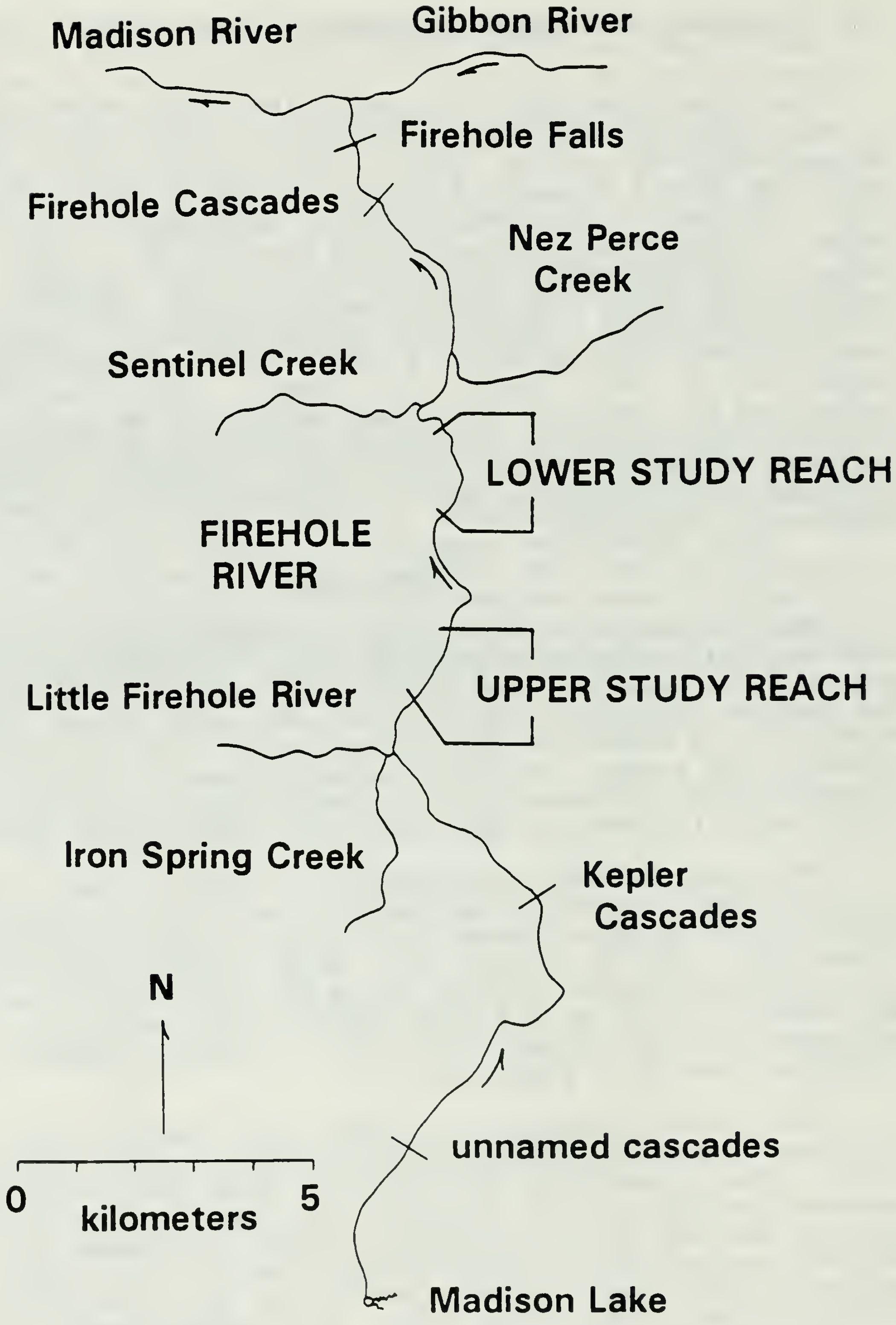

FIGURE 39.-Map of the Firehole River, Yellowstone National Park, showing locations of upper and lower study reaches, geologic barriers to the upstream movement of fish, and major tributaries.

Chemically, the Firehole River is a sodium-bicarbonate-chloride water (Wright and Mills 1967). Major ions reflect the composition of the rhyolite-dominated bedrock geology and geothermal processes in the watershed. Rhyolite is comprised largely of sodium and potassium aluminosilicates (Wright and Mills 1967). Geothermally heated waters passing through rhyolite leach out sodium at a higher rate than potassium (Boyd 1961). Such geothermal waters are also enriched by magmatic gases that cause elevated levels of bicarbonate and chloride (Allen and Day 1935). There are progressive increases in pH, total alkalinity, conductivity (largely from sodium chloride), and orthophosphate as the river flows through the geyser basins (Roeder 1966; Rasmussen 1968; Boylen and Brock 1973).

The progressive downstream increases in temperature and mineralization greatly enhance primary and secondary productivity of the Firehole River. Roeder (1966) found that composition of the benthic diatom community was related to total alkalinity, and diatom productivity was greatest in areas of high alkalinity. Benthic algal communities in Firehole River reaches receiving geothermal effluents had growth rates over five times higher and standing crops about 15 times higher than those in coldwater reaches upstream (Boylen and Brock 1973).

Correlation analyses led Rasmussen (1968) to conclude that the occurrence of aquatic macrophytes in the Firehole River depended largely upon interactions of stream gradient, current velocity, and sediment deposition, whereas the distribution of individual macrophyte species was strongly related to total alkalinity and temperature. There was a general downstream increase in percentage of the riverbed covered by macrophytes.

Armitage (1958) showed that biomass of benthic insects in the Firehole River was positively correlated with temperature and bicarbonate alkalinity and about seven times higher in stream reaches receiving geothermal effluents than in coldwater reaches. There was a significant positive correlation of Trichoptera (caddis fly) numbers in the benthos, a significant negative correlation of Ephemeroptera (mayfly) numbers, and no correlation of Diptera or Coleoptera, with progressive downstream increases in alkalinity. Sixteen of 33 benthic insect taxa preferred cool water, 12 preferred warm water, and five showed no temperature preference (Armitage 1961).

Four geologic barriers to the upstream movement of fish occur along the river: unnamed cascades near the headwaters, Kepler Cascades, Firehole Cascades, and Firehole Falls (Figure 39). Distribution of fish species in the Firehole River is strongly influenced by these barriers, and by river temperatures (Kaeding 1980; Kaya and Kaeding 1980; Jones et al. 1978; Koch 1990). The river above the unnamed cascades remains fishless (Jones et al. 1978), brown trout and brook trout *Salvelinus fontinalis* are found between the unnamed cascades and

Kepler Cascades, and brown trout, rainbow trout, and a few brook trout occur between Kepler Cascades and Firehole Falls. Downstream from Firehole Falls brown trout, rainbow trout, mountain whitefish *Prosopium williamsoni*, longnose dace *Rhinichthys cataractae*, mountain suckers *Catostomus platyrhynchus*, and mottled sculpin *Cottus bairdi* are common, and brook trout, cutthroat trout *O. clarki*, and Arctic grayling *Thymallus arcticus* are rare. Cutthroat trout occur in the upper reaches of the Little Firehole River.

Most of the river upstream from Kepler Cascades can be reached only by foot or horse, whereas the Grand Loop and Fountain Freight roads provide easy access to most of the river downstream from Kepler Cascades. Other developments near the Firehole River include the Old Faithful complex and Madison Campground.

History of Angling Regulations

Trout fishing on the Firehole River has been popular since the turn of the century (King 1897; Townsend 1897; Clark 1908). Early angling regulations included daily creel limits "not to exceed food needs" and no minimum-size restrictions. Creel limits were 20 fish in 1908, 10 in 1927, and 5 fish in 1946, and size restrictions fluctuated between none and a 203-mm minimum during this period. A fly-fishing-only regulation with no size restriction was imposed in 1951, when park managers became concerned that the dramatic increase in postwar angling pressure was resulting in the overharvest of trout.

Scientific investigations began to play a role in fisheries management in Yellowstone National Park in the mid-1950s. On the Firehole River, results of creel surveys and a fish population study conducted between 1953 and 1957 suggested to Benson et al. (1959) that rainbow trout were overharvested and brown trout and brook trout were "underfished," although angling regulations were not subsequently modified.

Results of a 1969 creel survey (Erman 1972) indicated the landings of rainbow trout had not changed since the mid-1950s, but brown trout landings had declined markedly. Because the apparent decline in the brown trout population was assumed to be the result of excessive angler harvest (Dean and Mills 1970), a two-fish, 406-mm minimum-size restriction was implemented in 1970 and remained in effect through 1986. The low creel rate (ca. 0.03 fish per hour) that resulted from the new regulation prompted Dean and Varley (1973) to call the Firehole River a "de facto catch-and-release fishery."

Despite the restrictive angling regulations, indications that large trout (>406 mm long) continued to be overharvested in the Firehole River remained. In his popular book on trout fishing, Brooks (1984) stated that experienced anglers who had fished the Firehole River for many years believed the average size of brown trout and rainbow trout had declined since the 1950s. A decline in mean length of Firehole River trout between 1977 and 1986 was suggested by data from the Volunteer Angler Report (VAR) system (described below; Jones et al. 1989). Also, results of an electrofishing survey conducted in 1987 indicated that the Biscuit Basin area of the Firehole River had the potential to produce large (>406 mm long) brown trout if the fish were protected from harvest (Jones et al. 1988).

Large trout in the Firehole River were protected by new angling regulations implemented in 1987 and in effect today. The daily creel limit of five fish may include no more than two brown trout, brown and brook trout have a 254-mm maximum-size limit, and all rainbow trout must be released. The catch-and-release regulation for rainbow trout resulted in part because many anglers cannot distinguish rainbow trout from the cutthroat trout or cutthroat trout X rainbow trout intergrades in the drainage, which are managed under a catch-and-release regulation.

Methods

Sport Fishery.-Data on angler effort, creel and landing rates, and species composition and length of fish landed were provided by the manned creel surveys of Benson et al. (1959) for 1953 through 1957, Dean and Mills (1970) and Erman (1972) for 1969, Dean and Mills (1971) for 1970, Dean and Varley (1973) for 1972, and Koch (1990) for 1988 and 1989. The river reaches surveyed and the seasonal survey periods differed little among studies, which were conducted between Biscuit Basin (where the road begins to parallel the river) and the Madison River, except that of Benson et al. (1959) had its upstream boundary at Kepler Cascades and that of Koch (1990) had its downstream boundary at Firehole Falls (Figure 39). Surveys began with the opening of the fishing season and were conducted through early September, except those of Benson et al. (1959) and Koch (1990) lasted through September.

The Volunteer Angler Report (VAR) system (Dean and Varley 1973, 1974; Dean et al. 1975; Varley et al. 1976; Jones et al. 1977) has been used since 1977 to estimate angling effort, creel and landing rates, mean length of caught fish, and other statistics for the Firehole River and many other park fisheries. Data provided voluntarily by anglers and submitted on postage-paid cards are used in the VAR system, which divides the Firehole River into lower (Madison River to Firehole Falls), middle (Firehole Falls to Kepler Cascades), and upper (upstream from Kepler Cascades) reaches for the computation of statistics. Data derived by the VAR system for the middle reach of the Firehole River are used in this report.

Although the precise Firehole River reach from which data were collected differed among some creel surveys and the VAR methodology, general comparisons among these data are appropriate. Most (74%) angler use of the Firehole River occurs in the middle reach (Jones et al. 1977), the reach effectively surveyed in all studies. Because the fishery in the middle reach is almost entirely for brown trout and rainbow trout, only data on these species are used in this report.

Fish population studies.-Fish population studies in the Firehole River were conducted by Benson et al. (1959) in the mid-1950s, Kaya (1978a and 1978b) and co-workers in the mid-1970s, and Jones et al. (1988, 1989) and Koch (1990) in the late 1980s. Although their methods differed, the studies generally had in common electrofishing surveys of two Firehole River reaches, here referred to as "upper" and "lower" (Figure 39). These reaches correspond approximately with Firehole River stations C and D (upper) and E and F (lower) of Benson et al. (1959), and have temperature regimes that may be characterized as "intermediate" and "warm," respectively (Kaeding and Kaya 1978). Data on relative abundance and length frequency of captured fish were available from these study areas.

Results and Discussion

Sport Fishery

Angler effort.-Estimated annual angler effort (hours spent fishing) on the Firehole River fluctuated nearly threefold among the creel surveys of the mid-1950s and 1969 to 1972, averaged about 21,000 angler hours, and reached a high near 34,500 angler hours in 1956 (Figure 40). Estimates from the VAR system showed angler effort averaged about 33,500 angler hours between 1977 and 1984, dropped to a low of 13,700 hours in 1988, and rose to a high of 50,800 hours in 1990. Although estimates of angler effort from VAR in 1988 and 1989 differed by 7.7 and 33.9 percent, respectively, from those of the concurrent manned creel surveys of Koch (1990), both techniques showed a sharp increase in angler effort between these years (Figure 40).

Wildfires affected much of Yellowstone National Park in 1988, when the recent low in angler effort occurred. Although the wildfires greatly reduced park visitation in 1988 and doubtless also reduced angling on the Firehole River that year, estimated angler effort had been declining during the 3 years prior to the fires (Figure 40).

McMichael and Kaya (1991) showed that landing rates for brown trout and rainbow trout were inversely related to temperature of the Madison River, Montana; landing rates became unsatisfactory ($\leq$0.4-0.6 fish/h) to anglers when river temperatures exceeded 19^{0}C. A similar relation may occur in geothermally heated regions of the Firehole River, where landing rate and angler effort within years decline sharply as water

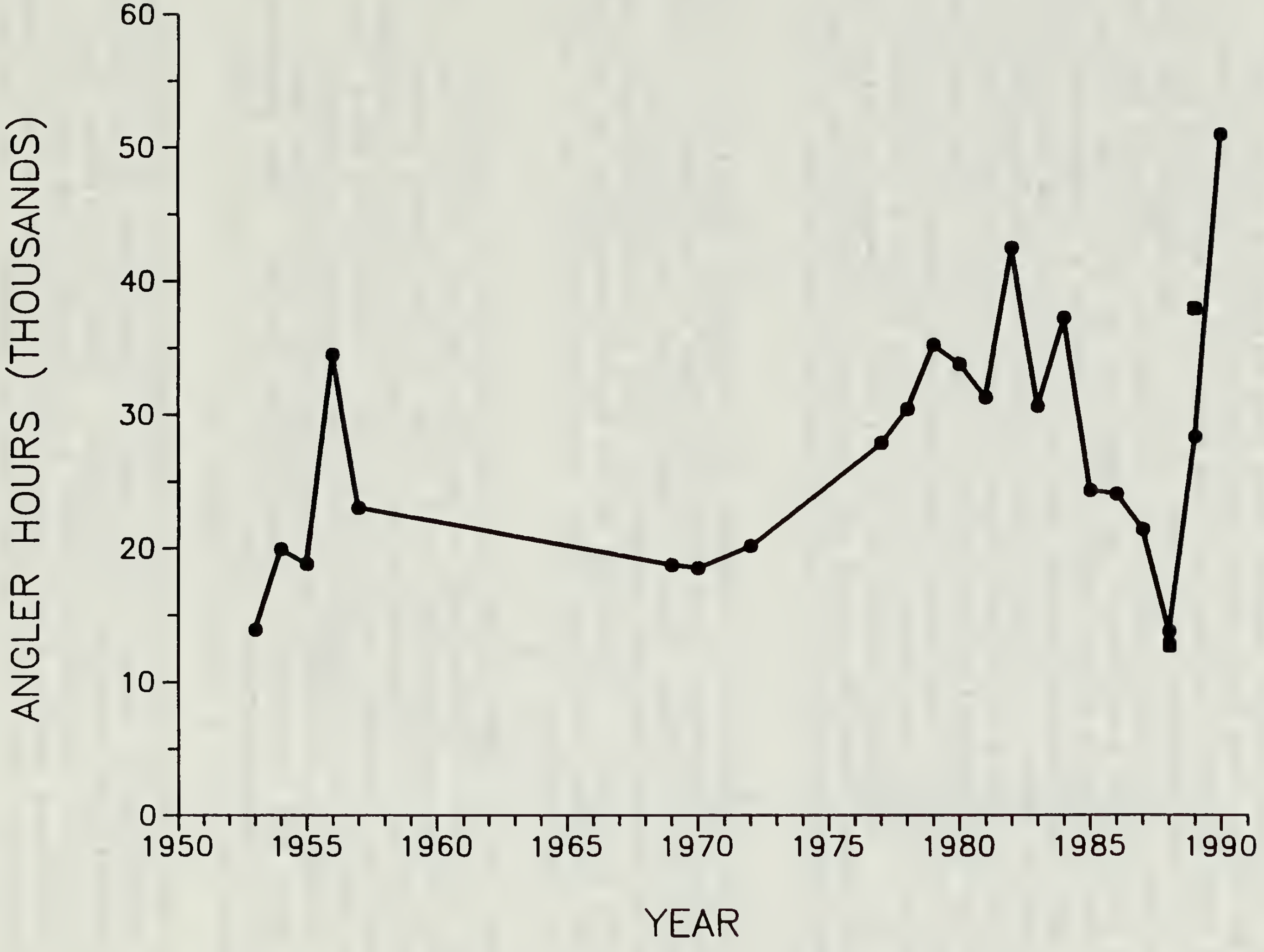

FIGURE 40.-Estimated annual angling effort on the Firehole River, Yellowstone National Park. Data for 1953 through 1972 were from manned creel surveys, whereas data for 1977 through 1990 were from the VAR system.

temperatures rise during summer (Koch 1990). The three summers preceding 1988 were especially warm and dry. Because the Firehole River would have exceeded 19^{0}C relatively early in the summers of those years, this may account for the decline in angler effort (Figure 40).

Creel and landing rates.-Estimated creel rate for brown trout and rainbow trout caught from the Firehole River was highest in 1955, the last year that trout were stocked, and declined between the surveys of the mid-1950s and 1969 to 1972 (Figure 41), as reported by Erman (1972). Estimates from the VAR system showed creel rate remained low between 1977 and 1990 and averaged 0.02 fish per hour. As reported by Dean and Varley (1973), the Firehole River essentially became a catch-and-release fishery upon implementation of the two-fish, 406-mm minimum-size restriction in 1970. Although new regulations implemented in 1987 allowed anglers to creel brown trout shorter than 254 mm, there was no accompanying increase in creel rate. In contrast with creel rate, the estimated landing rate for all trout from the Firehole River has shown an increasing trend since 1969 (Figure 41). Although Benson et al. (1959) did not provide data on landing rate, landing rates may have been similar to creel rates under the relatively liberal angling regulations of the mid-1950s.

Relative abundance of landed fish.-Because landings of brown trout from the Firehole River had declined while those of rainbow trout remained the same, Erman (1972) noted the relative abundance of these species landed in 1969 differed markedly from that of the mid-1950s. Whereas brown trout averaged 64 percent of landings between 1953 and 1957, they represented only 38.8 percent in 1969 (Figure 42).

Erman (1972) speculated that the reversal in relative abundance resulted from either a decline in the brown trout stock (ostensibly from overharvest) or a bias in his creel survey which, unlike that of Benson et al. (1959), excluded September, a productive time to fish for brown trout. Subsequent data from creel and VAR surveys substantiated the reversal in species relative abundance observed by Erman (1972) and showed that sampling bias had not been a contributing factor. The percentage brown trout landed has been relatively stable since at least 1969, averaging 34.8 percent (Figure 42).

Dean and Varley (1973) noted that the decline in brown trout landings reported by Erman (1972) had occurred during a time when angling regulations remained unchanged. They speculated that regulations alone were not a factor and the shift in species relative abundance among fish landed resulted from either changes in fish community structure or reduced vulnerability of brown trout to angling.

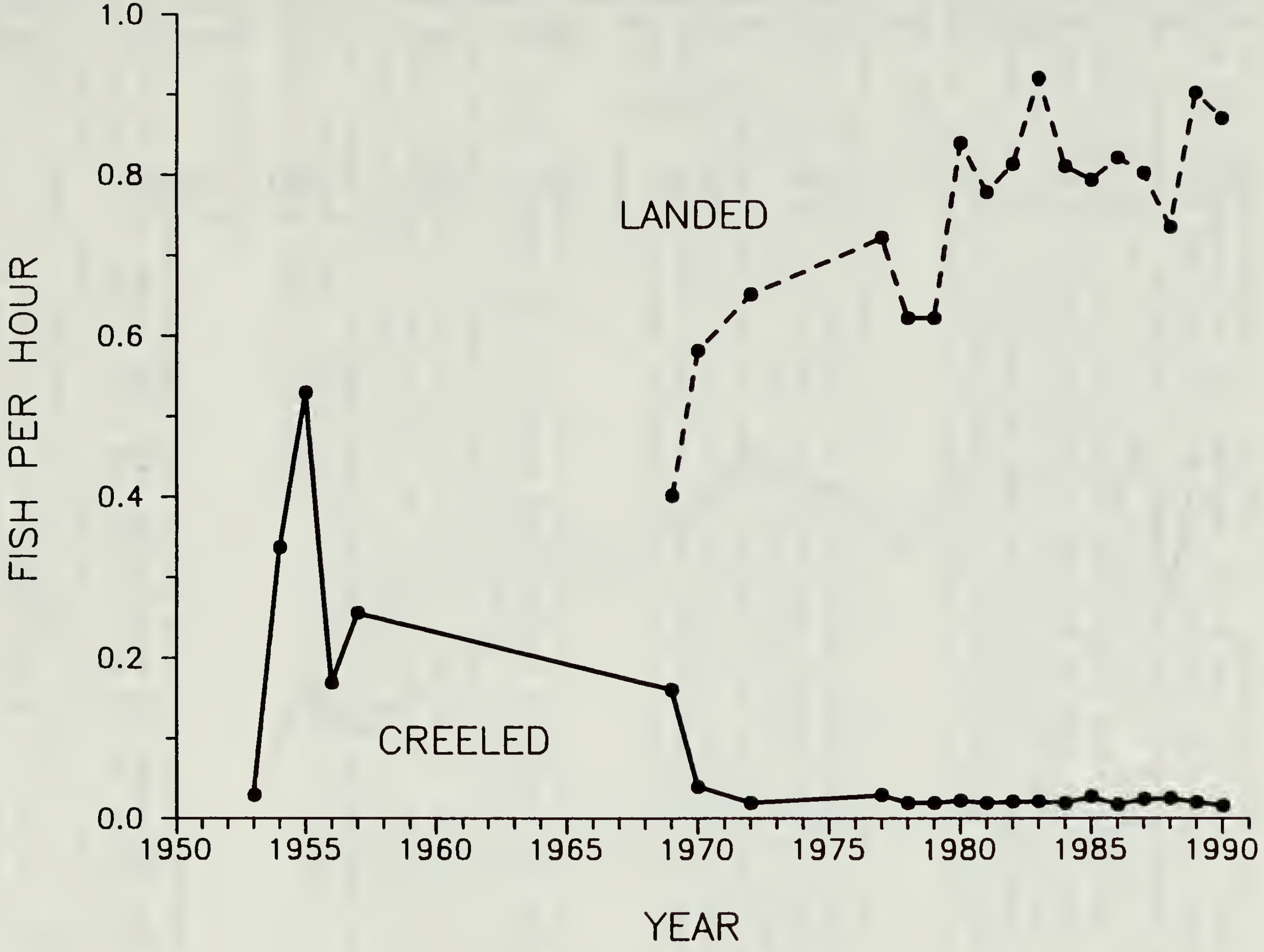

FIGURE 41.-Estimated mean-annual creel rate and mean-annual landing rate for all trout caught from the Firehole River, Yellowstone National Park. Data for 1953 through 1972 were from manned creel surveys, whereas data for 1977 through 1990 were from the VAR system.

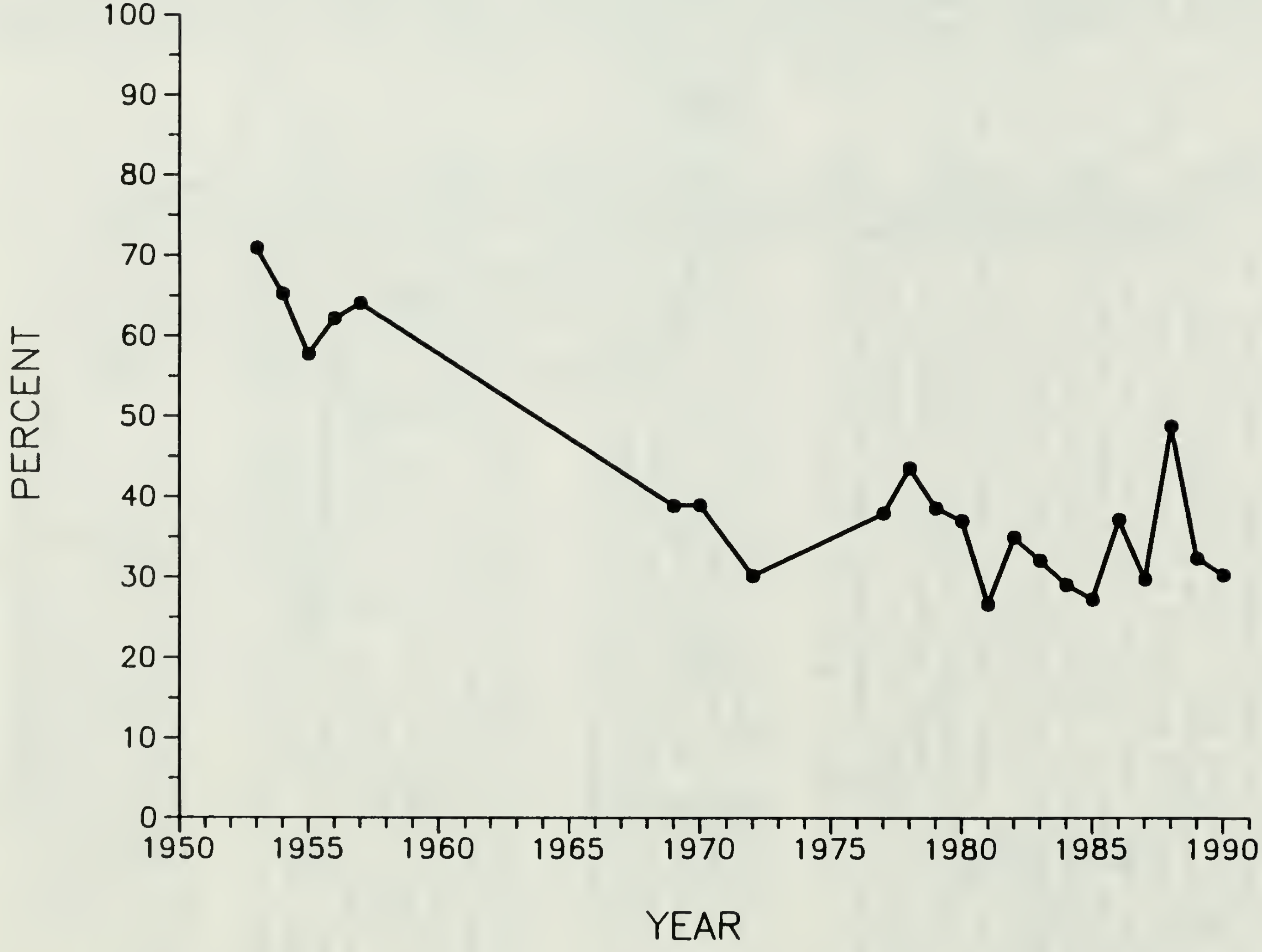

FIGURE 42.-Percent brown trout landed by anglers on the Firehole River, Yellowstone National Park. Rainbow trout was the other species caught. Data for 1953 through 1972 were from manned creel surveys, whereas data for 1977 through 1990 were from the VAR system.

Between 1951 and the end of stocking in 1955, the average-annual plant (primarily as fingerlings) into the Firehole River was 73,500 brown trout and 11,500 rainbow trout (Varley 1981). Dean and Varley (1973) suggested that wild brown trout available to anglers in the creel surveys of 1969 and later may have been less vulnerable to angling than the fish of hatchery origin present during the study of Benson et al. (1959).

Further investigations of the fish populations of the Firehole River began in 1974 (Kaya 1978a and 1978b). Among those studies was that of Kaya (1977), who showed that reproduction of fish was adversely affected by the elevated temperatures of the lower Firehole River study reach (Figure 39). Although brown trout and rainbow trout there had developed reproductive strategies that included spawning during winter when water temperatures are coolest, the incidence of normal gonadal development prior to spawning was much higher in rainbow trout. Moreover, fertilized eggs taken from several redds in the lower study area and raised in the laboratory all turned out to be rainbow trout.

These observations, along with other data described below, led Kaya and Kaeding (1980) to propose an alternative explanation for the reversal in species relative abundance among landed fish noted by Erman (1972). They hypothesized that the reversal in species relative abundance among landed fish reflected a reversal in species dominance in the trout community, and that the change in community structure resulted from the cessation of brown trout stocking and the greater adaptability of rainbow trout for life in the warm waters.

Size of landed trout.-Mean total length of brown trout and rainbow trout landed by anglers has varied during the relatively short period for which data are available (Figure 43). Mean length of brown trout and rainbow trout declined between the mid-1970s and 1988 and rose sharply in 1989, 2 years after angling regulations changed from a 406-mm minimum-size restriction to the 254-mm maximum-size restriction. Although an increase in the number of large trout caught was the anticipated effect of the change in regulations (Jones et al. 1988), an increase in mean length might also have resulted.

Population Studies

Species relative abundance in the river.-Results of population studies show relative abundance of brown trout and rainbow trout has changed in the upper and lower Firehole River study reaches between 1957 and the late 1980s. Brown trout represented about 65 percent of the trout community in the lower study reach in 1957, but were between 13 and 32 percent of that community during the mid-1970s and late 1980s (Figure 44). In the upper study reach, about 90 percent of the trout community was brown trout during 1957 and the mid-1970s, whereas brown

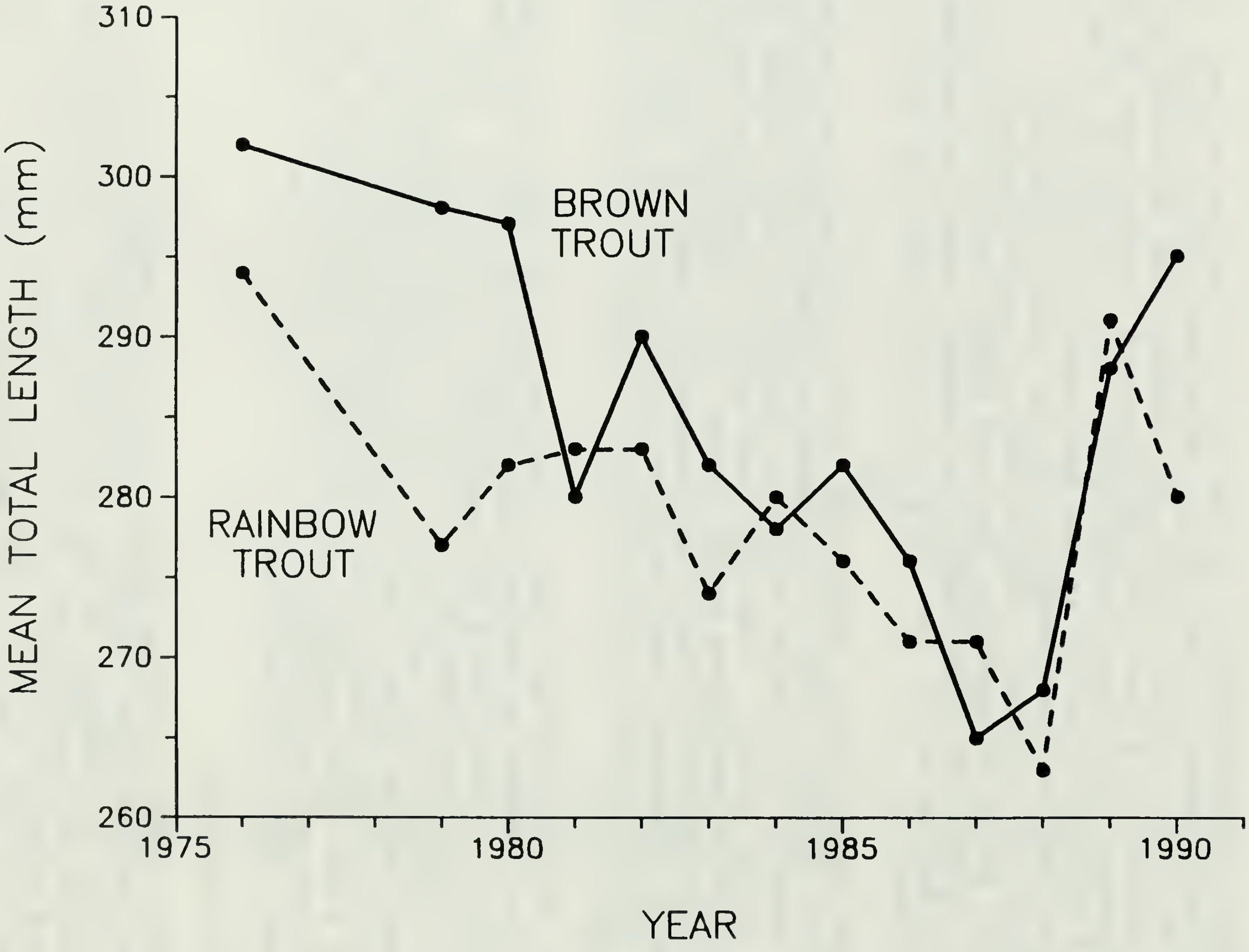

FIGURE 43.-Mean total length of brown trout and rainbow trout landed by anglers from the Firehole River, Yellowstone National Park. Data for 1953 through 1972 were from manned creel surveys, whereas data for 1977 through 1990 were from the VAR system.

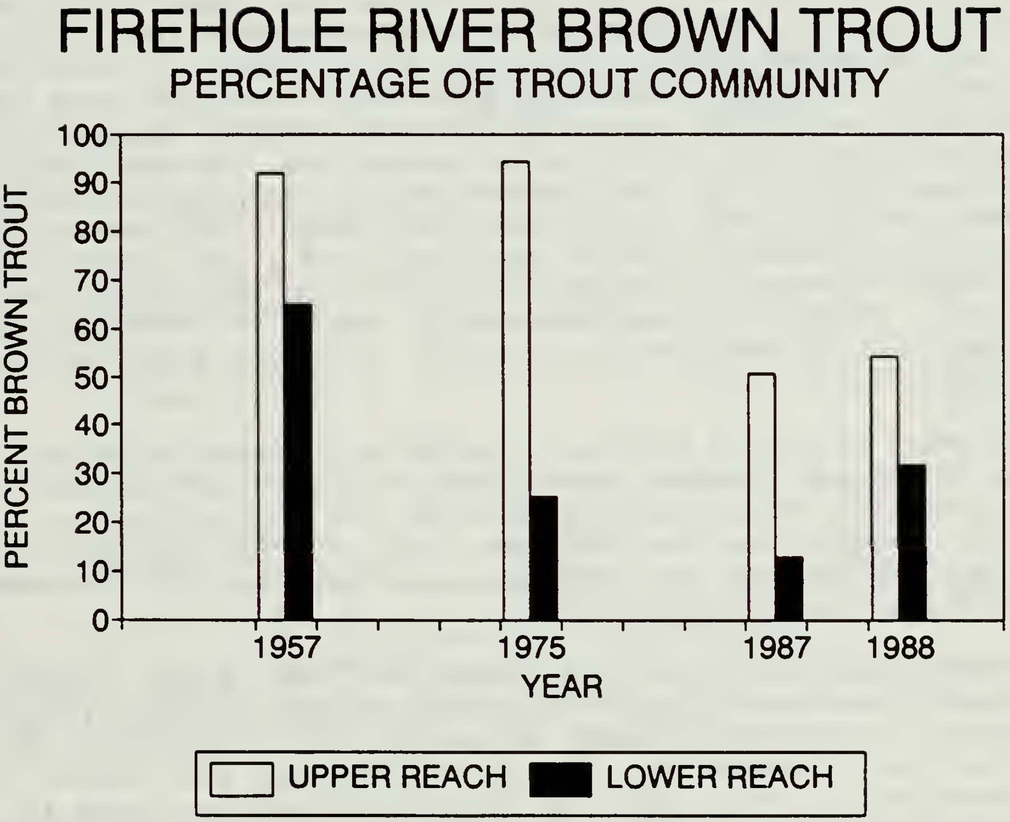

FIGURE 44.-Percent brown trout in the trout communities in the upper and lower study reaches of the Firehole River, Yellowstone National Park. Rainbow trout was the other species present. Data for 1957 are from Benson et al. (1959), those for 1975 are from Kaeding (1976), and data for 1987 and 1988 are from Jones et al. (1988, 1989). See Figure 1 for locations of study reaches.

trout and rainbow trout were about equally common there in the late 1980s.

Kaya and Kaeding (1980) noted that the longitudinal succession in relative abundance of brown trout and rainbow trout along the Firehole River in the mid-1970s differed in the warmest part of the river from that reported by Benson et al. (1959) for 1957; brown trout had been generally more common in that region in 1957. Kaya and Kaeding (1980) used this observation to support their hypothesis on the reversal in species relative abundance among landed fish noted by Erman (1972).

Data collected in the late 1980s (Jones et al. 1988, 1989) corroborated the change in species relative abundance in the warmest part of the river (which includes the lower study reach) reported by Kaya and Kaeding (1980) and suggested that similar changes may be occurring in the upper study reach (Figure 44). If such change in trout community structure resulted from the cessation of brown trout stocking and the greater adaptability of rainbow trout for life in the warm waters, as hypothesized by Kaya and Kaeding (1980), the changes would be evident first in the warmest part of the river (near the lower study reach) and subsequently in somewhat cooler regions (e.g., the upper study reach). This pattern of change is evident in the available data (Figure 44). Moreover, such changes in relative abundance of brown trout and rainbow trout along the Firehole River may not yet be complete.

Frequency of large trout.-Relative abundance of large (>400 mm) brown trout and rainbow trout were similar between the pooled, riverwide collections from 1957 and the mid-1970s (Table 24), suggesting that the two-fish, 406-mm minimum-size restriction implemented in 1970 had no effect on the frequency of large trout in the Firehole River.

Among collections from the upper and lower study reaches, large brown trout and rainbow trout were most frequent (14.2 and 3.9 percent) in the upper study reach in 1987. Although this observation led Jones et al. (1988) to conclude that brown trout in the upper study reach had the potential to grow large if protected from angler harvest, Jones et al. (1989) questioned that conclusion because a similar population study conducted in 1988 revealed reduced frequencies of large brown and rainbow trout (Jones et al. 1989; Table 24). Possible effects on the trout populations of the 254-mm maximum-size limit for brown trout and catch-and-release regulation for rainbow trout implemented in 1987 might not have been evident during the studies conducted in 1987 and 1988.

Spawning or other movements of large brown trout or rainbow trout would have little effect on species relative abundance within a river reach because large fish are a small part of the population; however, such movement could greatly affect the frequency of large fish within study reaches. Because sampling occurred entirely in September during some population studies (Benson et al. 1959; Jones et al. 1988, 1989)--a time when brown trout are moving to spawning areas (Kaeding 1980)--estimates of the relative frequency of large fish in the upper and lower study areas (Table 24) should be viewed with caution. "Riverwide" estimates of the frequency of large trout (Table 24) may be less affected by the movement of large fish.

TABLE 24.-Total number (N) of brown trout and rainbow trout longer than 100 mm total length collected during population studies conducted between 1957 and 1988, and percentage (%) of these fish that were longer than 400 mm.

		STUDY REACH					
		UPPER[a]		LOWER[a]		RIVERWIDE[b]	
YEAR	SPECIES	N	%	N	%	N	%
1957	Brown Trout	5,642	2.0	173	2.9	5,987	2.3
	Rainbow Trout	667	0.0	96	0.0	849	0.2
1974-75	Brown Trout	170	1.8	150	7.3	2,212	2.2
	Rainbow Trout	--		--		1,452	0.7
1987	Brown Trout	120	14.2	41	2.4	--	
	Rainbow Trout	118	3.9	276	0.0	--	
1988	Brown Trout		~5		~5		
	Rainbow Trout		~1		~0		

[a] Data for 1974-75 are from Kaeding, unpublished.

[b] Data for 1957 are those from population sampling points C to H (Upper Geyser Basin to Nez Perce Creek) of Benson et al. 1959; data for 1974-75 are from Kaya and Kaeding (1980).

Although brown trout longer than 406 mm could be legally harvested by anglers until 1987, the low creel rates evident since 1970 (Figure 41) did not suggest an important effect of angler harvest on the brown trout and rainbow trout populations. This led Kaya and Kaeding (1980) to hypothesize that the scarcity of large brown trout and rainbow trout in the Firehole River was not due to angler harvest but resulted from the limitations on trout growth imposed by the elevated river temperature regime and a diet consisting primarily of aquatic invertebrates.

Among population studies and their study reaches, the frequency of large brown trout was consistently greater than that of rainbow trout (Table 24). This suggests that the growth potential of rainbow trout is less than that of brown trout in the Firehole River.

Growth of fish.-Despite the difficulties encountered by most researchers who have used scales to study growth of brown trout and rainbow trout from the Firehole River, there has been remarkable similarity in estimates among studies. Scales taken from angler-creeled fish and analyzed by Benson et al. (1959) showed growth was rapid in both species (Figures 45 and 46). Benson et al. (1959) did not mention peculiarities in the formation of marks on scales from putative wild trout and used differences in the patterns of such marks to distinguish between wild and hatchery trout. On the basis of such analyses, Benson et al. (1959) concluded that only 0.29 percent of the stocked rainbow trout fingerlings and none of the brown trout fingerlings entered the creel.

Kaeding and Kaya (1978; also see Kaeding 1976) collected brown trout and rainbow trout throughout the year from three locations along the Firehole River, including the upper and lower study reaches. They found that brown trout and rainbow trout in the geothermally heated regions of the river produced as many as three marks on their scales each year. Jones et al. (1988) and Koch (1990) also reported multiple marks on scales of Firehole River trout.

Kaeding and Kaya (1978) were able to describe the growth of brown trout and rainbow trout from the Firehole River by giving all fish a 1 January birth date and then plotting backcalculated fish length at time of mark formation against the approximate calendar date that the mark was formed. Growth rates were similar between species and upper and lower study reaches. Similar estimates of the growth rate of brown trout and rainbow trout from the upper and lower study reaches were made by Jones et al. (1988) and Koch (1990; Figures 45 and 46).

Growth rates of fishes are characterized by large variation among individuals, particularly among older fish within populations. Although the data provided in Figures 45 and 46 cannot be tested to reveal possible significant differences among means within fish ages because most estimates of variance about these means are not available, the available variances are large (Kaeding 1976; Kaeding and Kaya 1978) and make the occurrence of significant ($P < 0.05$) differences unlikely. The data indicate that there have been no long-term changes in the growth rate of brown trout in the geothermally heated region of the Firehole River.

Synthesis

Two major changes have occurred in the fishery of the Firehole River since the mid-1950s. The first, noted by Erman

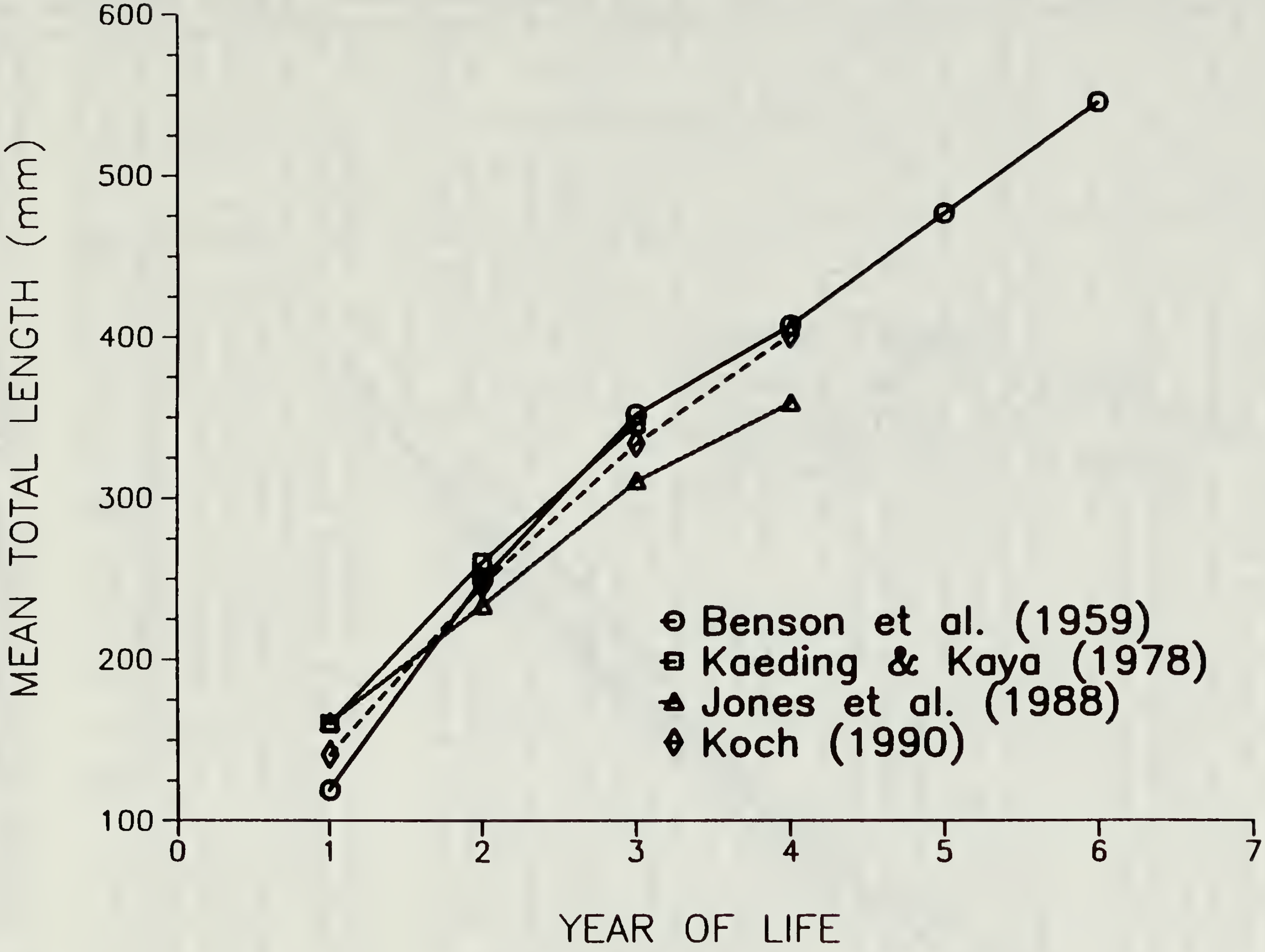

FIGURE 45.-Estimated growth rates of brown trout from the Firehole River, Yellowstone National Park. Data from Jones et al (1988) and Koch (1990) are averages of mean values for upper and lower study reaches.

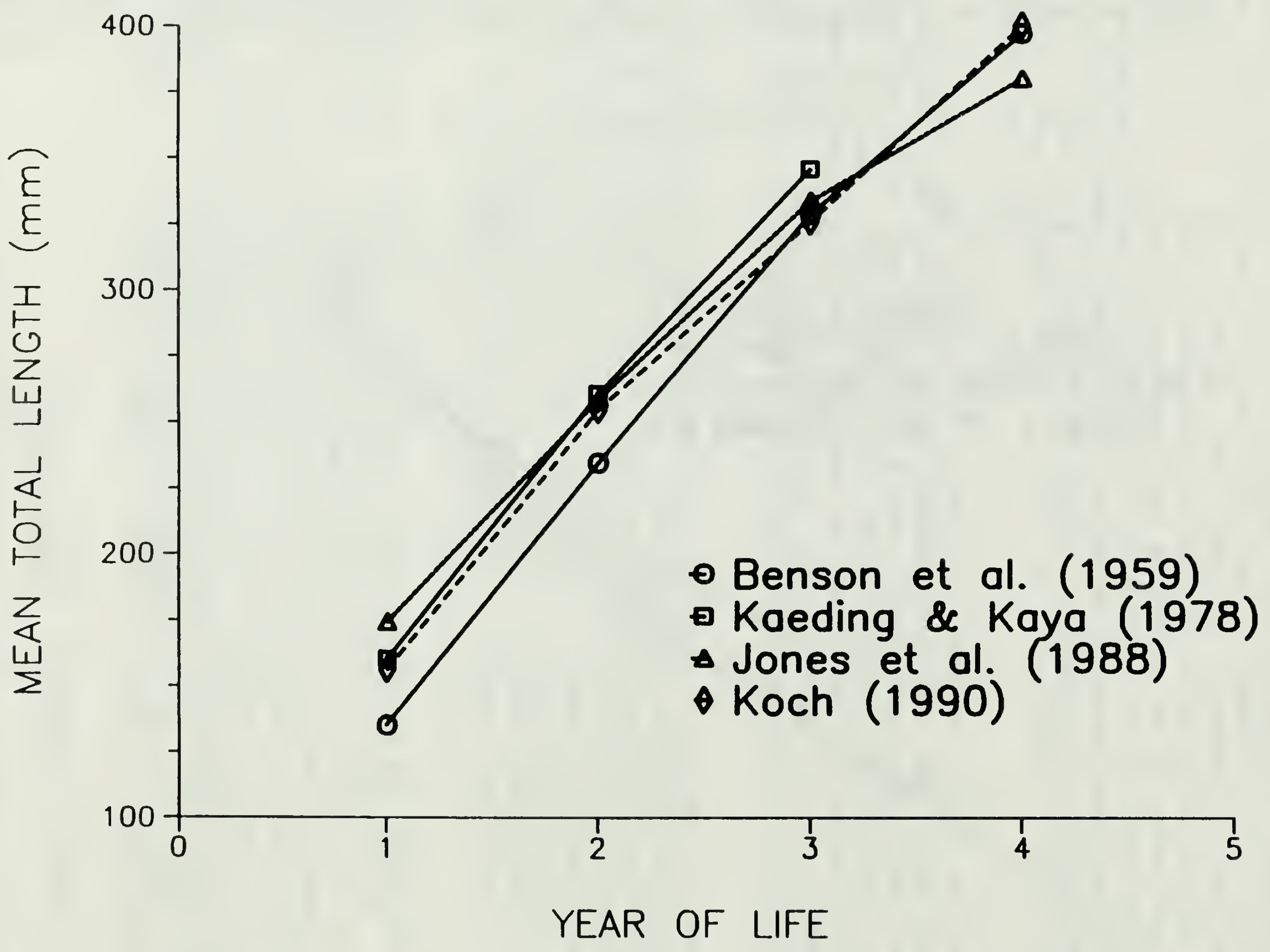

FIGURE 46.-Estimated growth rates of rainbow trout from the Firehole River, Yellowstone National Park. Data from Jones et al (1988) and Koch (1990) are averages of mean values for upper and lower study reaches.

(1972), was the reversal in species relative abundance of landed fish between the mid-1950s and 1969 (Figure 42). Kaya and Kaeding (1980) hypothesized that the reversal in species relative abundance of landed fish reflected a reversal in species dominance in the trout community, and that the change in community structure resulted from the cessation of brown trout stocking and the greater adaptability of rainbow trout for life in the warm waters. An alternative hypothesis, sometimes expressed by local fishermen, is that a major earthquake near the Firehole River in 1959 (the Hebgen Lake earthquake) caused an increase in the discharge of geothermally heated waters to the river and an increase in river temperature regime that was particularly detrimental to brown trout survival.

Studies do not show a long-term increase in the heat energy that geothermal geysers and springs contribute to the Firehole River, however. Burkhalter (1979) used remote sensing to estimate the power (heat) added by geothermal discharges to the Firehole River during the mid-1970s as 425 megawatts (MW), an estimate similar to one (448.5 MW) made more than four decades earlier by Allen and Day (1935) and based on measurements of heat contributions of individual geysers and thermal springs.

Fournier (1989) used the river-chloride-inventory method to calculate the instantaneous flux of thermal water discharged by all chloride-rich hot-spring systems in the park for the years 1966 and 1967 and 1983-1986. Total heat output was relatively constant, although a 15 to 20 percent increase occurred during the several months that preceded the 1983 Mt. Borah (Idaho) earthquake (7.3 magnitude). Fournier stated that hydrothermal activity in Yellowstone National Park has been continuous at about its present level for at least 15,000 yr and probably much longer. It is unlikely that short-term events, such as the increase in geothermal heat output that preceded the Mt. Borah earthquake, would result in long-term changes in the fish community of the Firehole River.

The hypothesis of Kaya and Kaeding (1980) on the reversal in species relative abundance among landed fish assumes that the stocking of brown trout that ended in 1955 contributed importantly to the Firehole River fishery. This is in sharp contrast with a major conclusion of Benson et al. (1959), who reported that wild trout from the Firehole River could be distinguished from hatchery trout on the basis of marks on scales and used that technique to estimate that only 0.29 percent of the stocked rainbow trout fingerlings and none of the brown trout fingerlings entered the creel.

Further study is needed to determine if changes in species relative abundance in the fish community of the Firehole River are continuing, particularly in the upper study reach and regions upstream. Sampling at many or all of the eight study sites of Benson et al. (1959) between Kepler Cascades and Firehole Falls may be the best way to obtain data on species relative abundance and length frequency comparable among all studies.

The second major change in the Firehole River fishery resulted from implementation of the two-fish, 406-mm minimum-size restriction in 1970. Implemented because the decline in the brown trout population was assumed to be the result of excessive angler harvest (Dean and Mills 1970), the regulation brought about not only a "de facto catch-and-release fishery" (Dean and Varley 1973) but a long-term increase in landing rate (Figure 41). The increase in landing rate suggests that the new regulation served to increase fish abundance in the Firehole River, although there are no comparable data on fish abundance that might support this speculation. The angler creel of fish that occurred under the former regulations may have had a limiting effect on the fish populations.

Although Dean and Mills (1971) assumed that the two-fish, 406-mm minimum-size regulation implemented in 1970 would increase the number of large trout (> 406 mm), there is no subsequent evidence of such an increase (Table 24). Minimum-size limits do not protect large fish from harvest. Further study is needed to determine if the 254-mm maximum-size restriction implemented in 1987 is leading to an increase in the relative abundance of large trout.

Although anglers could legally creel brown trout shorter than 254-mm beginning in 1987, there was no accompanying increase in creel rate (Figure 41). Most anglers may consider such fish too small to keep, or keeping fish of any size may be of minor importance to most fishermen on the Firehole River. The fly-fishing-only regulation on the Firehole River may attract anglers who prefer to release the fish that they land.

POSTFIRE OBSERVATIONS ON STREAM FISHERIES IN YELLOWSTONE NATIONAL PARK

In 1988, forest fires burned approximately 322,000 hectares in Yellowstone National Park (National Park Service 1989), slightly less than 40% of the total park area. Fire activity covered many habitat types from dense old growth forest to areas of open, sagebrush-dominated grasslands. Small, high-gradient stream drainages, as well as larger, low-gradient watersheds, were burned. Hypothesized short-term (1-5 years) effects of this large-scale fire event included severe erosion of stream channels in response to increases in spring runoff (Hydrology Assessment Team 1988; Christensen et al. 1989), potentially large introductions of sediment from upland areas into streams in burned drainages (GYCC 1989), and reduction in the abundance or diversity of stream macroinvertebrates (Minshall et al. 1989) and fish (Christensen et al. 1989).

The 1988 fires in Yellowstone Park present an unprecedented opportunity to examine the influences of large-scale forest fires on stream systems. Some postfire research in the park has been concentrated on small streams (1st to 4th order) where postfire effects could be most dramatic (e.g., Albin 1979; Minshall et al. 1991); in other research, effects on fisheries were not a study objective (Stottlemeyer 1987). Consequently, the primary objective of the current study was to document annual variation in the environment of larger (e.g., 4th to 6th order) streams and associated sport fisheries in Yellowstone National Park during the postfire period.

Study Areas

After the cessation of fires in fall 1988, and prior to the first postfire runoff in spring 1989, study sites were established on six streams in either partially or extensively burned watersheds. Criteria used for selecting study areas included importance as a sport fishery, amount of burned area in the watershed, availability of prefire fishery data, and accessibility. All study sites were in 4th to 6th order streams in areas downstream from most of the fire activity. Within the Lamar River drainage, study reaches were in nonforested sections of the Lamar River mainstem and its two principle tributaries, Slough Creek and Soda Butte Creek (Figure 47). Less than 10% of the Soda Butte Creek watershed burned, but nearly half of the drainages upstream from the study sites on Slough Creek and the Lamar River were burned.

The remaining three study areas were in the Madison River watershed (Figure 48). In contrast to the Lamar River study reaches, sites in the Madison River watershed were in or adjacent to burned forest riparian areas. Amount burned in these

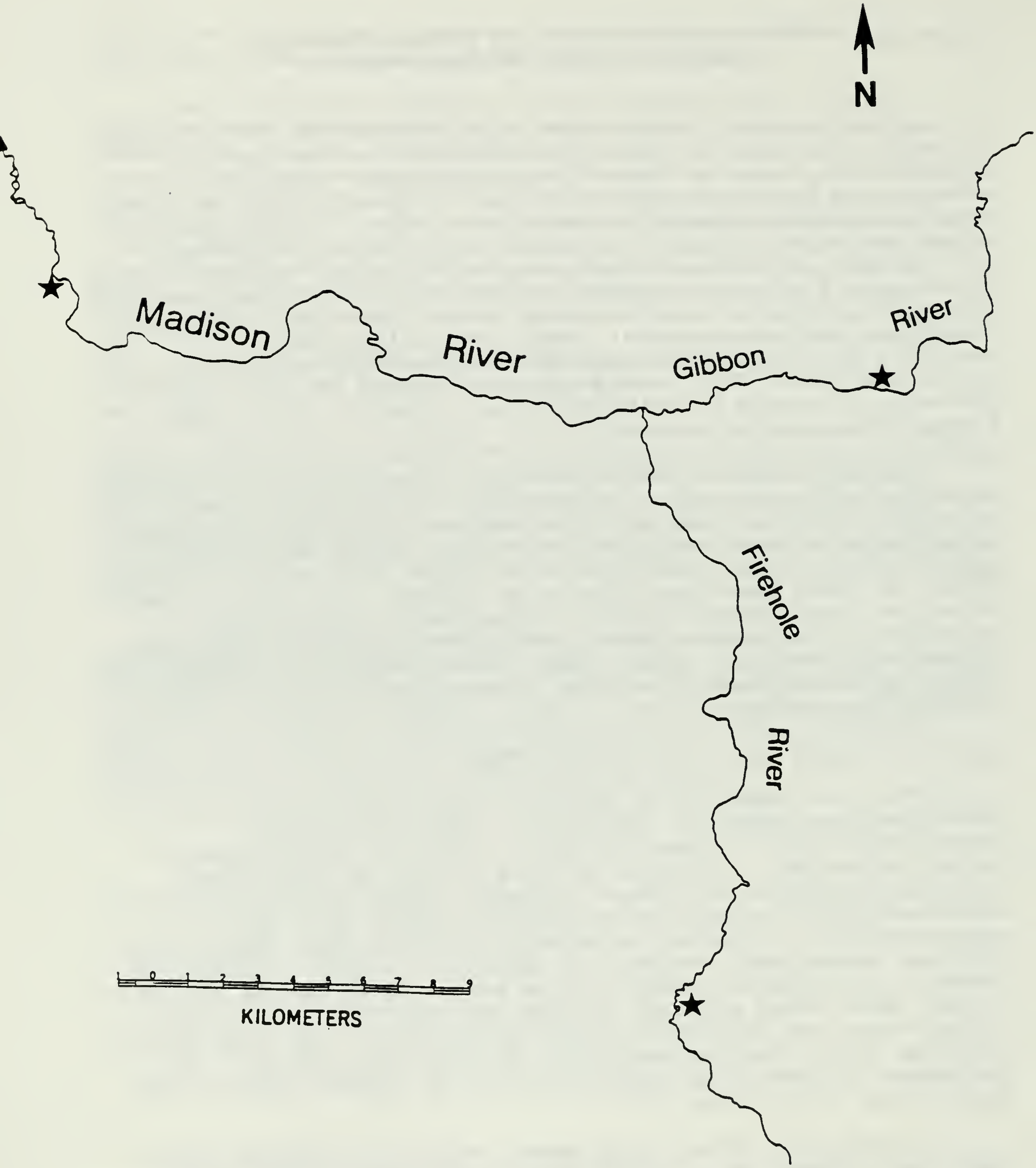

FIGURE 47.-Location of postfire study sites within the Lamar River drainage (1988-1991).

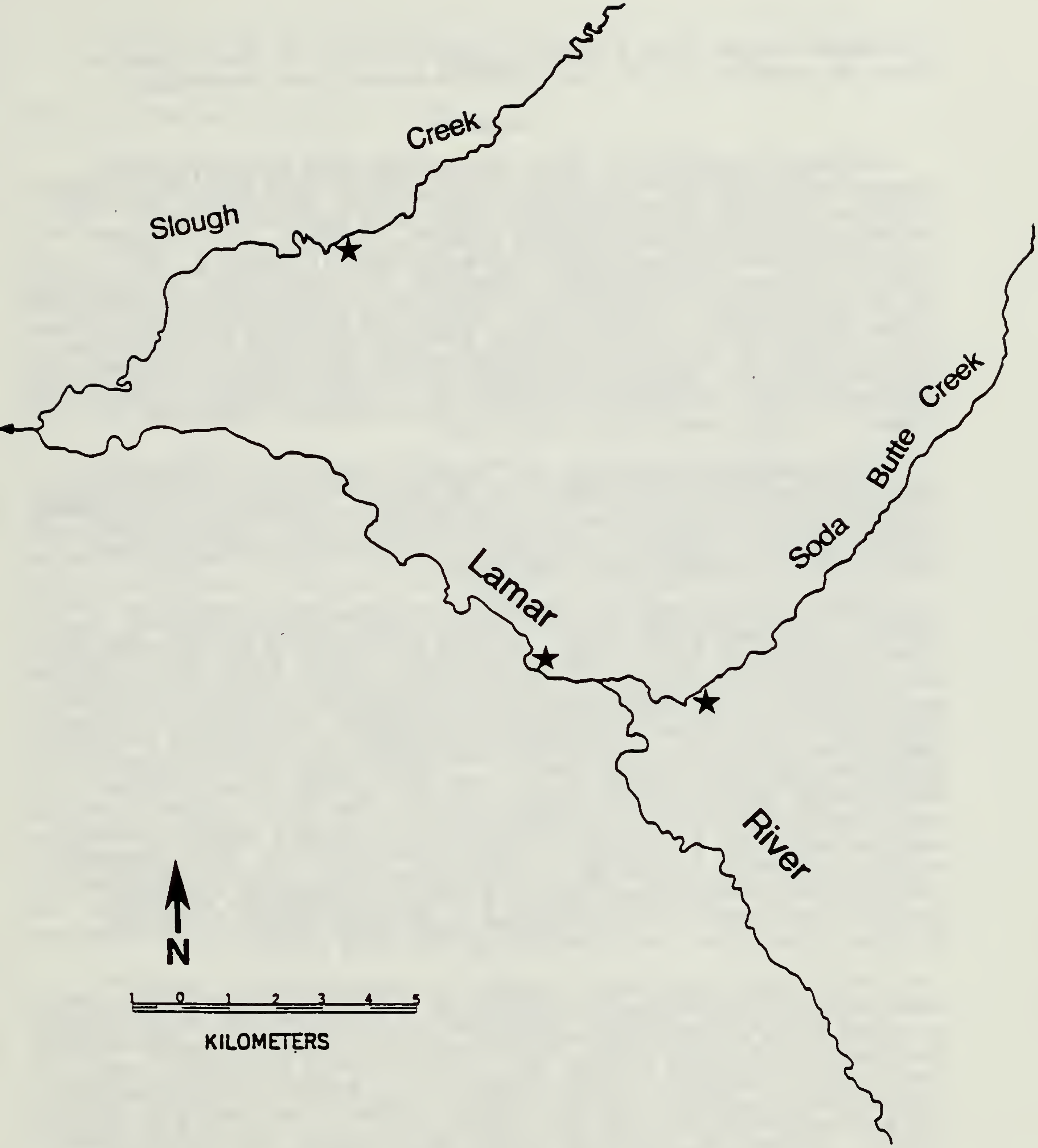

FIGURE 48.-Postfire study sites within the Madison River drainage (1988-1991).

drainages ranged from slightly less than 40% in the Firehole River to nearly 67% of the entire Madison River watershed.

Methods

At each study site, three transects were established and stream habitat data, including estimates of streambank erosion rates and stream bottom composition, were obtained. Data collection procedures followed those in Platts et al. (1983, 1987) with several modifications described in Jones et al. (1990). Twenty-two habitat parameters were measured or estimated at each transect. In addition, discharge was measured at the first transect by the midsection method (Buchanan and Somers 1969). Yearly variation in stream substrate composition was detected using a multiple analysis of variance (MANOVA) technique (Hintze 1991). Transect data were collected at each site in summer or fall 1989, 1990, and 1991.

During each sample period, instantaneous water temperature was obtained with a hand-held thermometer. Specific conductance (conductivity) and pH were also measured in the field. Other water chemistry results included in this report are analyses performed by a commercial laboratory.

Three benthic macroinvertebrate samples were obtained annually at each study site. A 0.09 m^2 modified Surber sampler with a mesh size of 0.28 mm (Winget and Mangum 1979) was used to sample macroinvertebrates. Collected specimens were identified and analyzed by an independent investigator. Results in this report include estimated abundance (number/m^2), species richness (number of different taxa), DAT (dominance and taxa) diversity index (Winget and Mangum 1979), and functional feeding group composition (Merritt and Cummins 1984). The Biotic Condition Index (BCI), which compare the macroinvertebrate habitat under consideration to a "pristine" theoretical habitat that supports species with very specific environmental requirements (Mangum 1986b), was incorporated into the macroinvertebrate analyses. Results from only the first three macroinvertebrate sampling periods (1988-1990) were available for this report.

Fish populations were sampled by electrofishing from a 4-m raft that had boom-mounted electrodes. Shocking was usually done at night with a pulsed-DC system. Captured fish were measured to the nearest mm total length (TL). Fish from a subsample were individually weighed to the nearest 2 g. Scales were collected for age and growth analysis. Relative abundance, average length, and estimated average age of captured fish are examined in this report. Populations in each stream were sampled at least once during the postfire period to facilitate comparisons with prefire conditions; Soda Butte Creek and the Lamar River were the only sites where fish were sampled annually.

Results

Habitat characteristics

Lamar River watershed.-In fall 1988, estimated streambank erosion (percent streambank alteration) at the transect sites ranged from less than 40% in Soda Butte Creek to more than 50% in the Lamar River. Undercut banks were scarce in all three study streams and channel vegetative cover (downed trees or aquatic macrophytes) was absent or uncommon (Tables 25-27). Cobble was the predominant substrate material in Soda Butte Creek and the Lamar River, but gravel and sand covered most of the bottom of Slough Creek. Riparian zones consisted primarily of grassy streambanks interspersed with unvegetated areas. On the initial survey date (October 1988), streamside vegetation was short and did not overhang into the stream channel (Tables 25-27).

Compared to the fall 1988 survey, stream discharge more than doubled between 1989 and 1991 at all Lamar River drainage sites. Average stream depth increased with the increased flows, but stream width exhibited less variability. Although the Lamar River revealed little change in erosion rate between 1988 and 1991, estimated streambank alteration increased in Soda Butte Creek and Slough Creek and approximately half of the streambanks from all three streams were eroded in 1991 (Tables 25-27). Pool-width riffle-width ratio was similar among years in Soda Butte Creek and the Lamar River; but this habitat characteristic changed in Slough Creek where pools were predominant in 1991. Substrate composition changed significantly in Slough Creek ($F = 3.47$, $P = 0.01$) and in Soda Butte Creek ($F = 2.55$, $P = 0.04$) from 1988 to 1991. In Slough Creek, the percentage of silt increased from 1988 to 1991 ($F = 11.42$, $P < 0.01$), but a marked decrease in silt ($F = 13.76$, $P < 0.01$) was observed in Soda Butte Creek. Annual variation in substrate composition in the Lamar River was not significant ($F = 1.38$, $P = 0.27$). Amount of channel vegetation was unchanged or varied slightly in the Lamar River and Soda Butte Creek; however, an increase in vegetation was observed in Slough Creek 2 years postfire.

Madison River watershed.-In fall 1988, less than 25% of the streambanks appeared eroded at the Madison River watershed study sites. Streambank vegetative stability was rated high at all sites. Undercut banks were common and ranged from a mean width of 2 cm in the Madison River to 12 cm in the Firehole River. Undercut depth ("stream-shore water depth") ranged from 5 cm in the Madison River to 11 cm in the Firehole River (Tables 28-30). In contrast to the Lamar River watershed sites, channel vegetation cover (aquatic macrophytes and downed trees) was abundant in the Madison River watershed study reaches and ranged from 1.3 m at the Gibbon River transect sites to 5.5 m in the Madison River. More than 90% of the substrate in the Firehole River was gravel, sand, and silt in fall 1988. In contrast, the Gibbon River and the Madison River substrates were primarily

TABLE 25.-Drainage basin characteristics and habitat features of the first meadow section of Slough Creek, 1988 to 1991.

Stream order	V
Length (km)	2.1
Elevation:	
Maximum (m)	1,974
Minimum (m)	1,966
Drainage size (hectares)	36,034
Stream type[a]	C3

Habitat features	1988	1989	1990	1991
Sample date	10/19	8/2	8/8	8/20
Time	1410	--	1500	1045
Water column:				
Flow (m^3/s)	1.48	2.88	2.17	1.23
Channel width (m)	32.9	35.8	32.6	34.6
Stream width (m)	21.4	28.7	28.2	27.2
Stream depth (cm)	19	36	28	24
Stream shore water depth (cm)	0	0	0	0
Riffle width (m)	10.0	2.0	4.5	5.3
Pools:				
Width (m)	8.6	20.0	14.2	11.0
Quality	2.5	2.9	2.5	2.3
Feature	2	2,3	3,1	2,3
Solar angle (°)	145	152	153.3	152
Channel morphology				
Streambank alteration (%)	45.8	31.7	55.8	51.7
Vegetative stability	3.5	1.8	2.3	3.2
Undercut (cm)	0	0	0	0
Channel-bank angle (°)	144	168	161.7	162
Stream bottom:				
Gradient (%)	0.1	0.4	0.5	0.6
Sinuosity	1.15	1.09	1.08	1.07
Substrate:				
Boulder (> 305 mm)	0	0	0	0
Cobble (64-305 mm)	8.0	9.1	14.9	20.7
Gravel (2-64 mm)	59.5	59.7	27.0	28.7
Sand (0.6-2 mm)	28.4	20.8	52.1	21.0
Silt (<0.6 mm)	4.0	10.4	6.1	29.6
Embeddedness (%)	10.0	28.3	18.3	15.0
Channel vegetative cover (cm)	0	0	99	15
Riparian zone:				
Streamside cover type	1.8	2.2	1.8	1.8
Vegetative use (%)	33.3	10.0	7.5	6.7
Vegetation overhang (cm)	0	0	0	8
Habitat type	4,2	12,6	14,6	3,8

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[a] After Rosgen (1985).

[b] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

TABLE 26.-Drainage basin characteristics and habitat features of Soda Butte Creek, 1988 to 1991.

Stream order	IV
Length (km)	3.26
Elevation:	
Maximum (m)	2,016.3
Minimum (m)	2,002.5
Drainage Size (hectares)	20,938.2
Stream type[a]	C1

Habitat features	1988	1989	1990	1991
Sample date	11/3	8/31	9/27	9/11
Time	1030	1015	1030	1730
Water column:				
Flow (m^3/s)	0.684	1.618	1.587	2.237
Channel width (m)	24.4	23.1	22.9	31.2
Stream width (m)	13.3	14.6	13.7	15.4
Stream depth (cm)	17	25	21	25
Stream shore water depth (cm)	0	0	1	0
Riffle width (m)	10.7	11.9	10.9	11.2
Pools:				
Width (m)	1.2	1.1	1.1	1.8
Quality	1.2	1.0	1.0	1.1
Feature[b]	3,4	3	3	3,4
Solar angle (°)	155.7	156.2	157.7	154
Channel morphology				
Streambank alteration (%)	38.3	50.8	61.7	59.2
Vegetative stability	2.5	2.83	2.5	2.8
Undercut (cm)	0	0.1	0.1	5
Channel-bank angle (°)	149.2	148.3	160.8	150
Stream bottom:				
Gradient (%)	0.6	0.7	0.6	1.0
Sinuosity	1.18	1.08	1.09	1.11
Substrate:				
Bedrock				
Boulder (> 305 mm)	2.3	2.8	2.4	5.3
Cobble (64-305 mm)	70.4	91.6	76.4	79.0
Gravel (2-64 mm)	18.4	3.5	10.0	10.3
Sand (0.6-2 mm)	2.3	0.7	5.2	4.8
Silt (< 0.6 mm)	6.8	1.4	6.0	0.6
Embeddedness (%)	50.0	40.0	40.0	11.7
Channel vegetative cover (cm)	13	10	14	14
Riparian zone:				
Streamside cover type	2.2	2.0	2.2	1.8
Vegetative use (%)	13.3	8.3	5.8	6.7
Vegetation overhang (cm)	0	0	0	4
Habitat type	12,6	8,4	12,8	9,12

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[a] After Rosgen (1985).

[b] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

TABLE 27.-Drainage basin characteristics and habitat features of Lamar River near the Lamar River picnic area, 1988 to 1991.

Stream order	V
Length (km)	2.277
Elevation:	
Maximum (m)	2,002.5
Minimum (m)	1,988.8
Drainage Size (hectares)	99,816.1
Stream type[a]	C1

Habitat features	1988	1989	1990	1991
Sample date	11/6	9/7	9/6	9/5
Time	0945	1100	1530	1045
Water column:				
Flow (m^3/s)	1.599	3.860	6.198	2.920
Channel width (m)	41.7	38.0	44.6	50.4
Stream width (m)	24.9	26.8	26.8	25.9
Stream depth (cm)	28	38	42	40
Stream shore water depth (cm)	0	2	0	0
Riffle width (m)	2.1	2.9	0.8	2.3
Pools:				
Width (m)	17.1	17.9	18.7	17.7
Quality	3.8	2.8	3.3	3.3
Feature[b]	4,2	2,4	2,4	2,4
Solar angle (°)	152.3	151.3	153.3	154
Channel morphology				
Streambank alteration (%)	52.5	52.5	50.0	51.7
Vegetative stability	3.2	3.0	2.8	3.0
Undercut (cm)	0	0.3	0	7
Channel-bank angle (°)	156.7	137.5	160.0	148.0
Stream bottom:				
Gradient (%)	1.1	0.6	1.0	1.0
Sinuosity	1.03	1.03	1.04	1.06
Substrate: (%)				
Bedrock				
Boulder (>305 mm)	9.6	3.2	4.2	16.1
Cobble (64-305 mm)	54.8	54.6	61.1	38.1
Gravel (2-64 mm)	6.9	12.0	14.9	17.5
Sand (0.6-2 mm)	11.2	20.9	10.3	13.6
Silt (<0.6 mm)	17.4	9.3	9.5	14.7
Embeddedness (%)	22	62	32	28.3
Channel vegetative cover (cm)	0	0	0	0
Riparian zone:				
Streamside cover type	2.5	1.7	1.5	1.5
Vegetative use (%)	26	17	14	16.7
Vegetation overhang (cm)	0	0	6	6
8,11 Habitat type	8,12	8,3	9,13	

[a] After Rosgen (1985).

[b] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock;
5 = stream channel; 6 = fine sediments; 7 = streambank.

TABLE 28.-Drainage basin characteristics and habitat features of the Firehole River, 1988 to 1991.

Stream order	V
Length (km)	2.37
Elevation:	
Maximum (m)	2,211.3
Minimum (m)	2,209.8
Drainage Size (hectares)	23,702.7
Stream Type	C3

Habitat features	1988	1989	1990	1991
Sample date	11/1	2/27	8/02	10/04
Time	1020	1445	0900	1045
Water column:				
Flow (m^3/s)	3.30	3.62	3.62	3.59
Channel width (m)	21.5	20.1	20.0	21.1
Stream width (m)	16.2	18.0	18.2	17.1
Stream depth (cm)	32	30	33	33
Stream shore water depth (cm)	11	23	26	21
Riffle width (m)	5.6	1.8	9.4	3.9
Pools:				
Width (m)	5.3	8.1	3.8	6.6
Quality	3.0	3.1	2.7	3.9
Feature	2,7	2,7	1,2,3	2,1,6
Solar angle (°)	139.7	143.3	140.3	144
Channel morphology				
Streambank alteration (%)	11.7	25.4	31.3	39.2
Vegetative stability	4.0	3.6	3.6	3.8
Undercut (cm)	12	13	18	16
Channel-bank angle (°)	90.8	88.3	81.3	88
Stream bottom:				
Gradient (%)	0.5	1.0	0.5	0.8
Sinuosity	1.43	1.49	1.48	1.52
Substrate:				
Bedrock			5.2	14.7
Boulder (> 305 mm)	8.3	9.7		
Cobble (64-305 mm)	0.5		1.1	
Gravel (2-64 mm)	48.2	28.2	43.4	28.0
Sand (0.6-2 mm)	18.3	19.1	22.7	31.1
Silt (< 0.6 mm)	24.3	43.0	27.7	26.2
Embeddedness (%)	23.3	1.7	31.7	3.3
Channel vegetative cover (cm)	241	439	646	598
Riparian zone:				
Streamside cover type	2.0	1.9	1.9	2.0
Vegetative use (%)	27.5	18.8	12.5	25.8
Vegetation overhang (cm)	3	23	15	9
Habitat type	12	12,13	12,8	12,13

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[a] After Rosgen (1985).

[b] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

TABLE 29.-Drainage basin characteristics and habitat features of the Gibbon River near Canyon Creek, 1988-1991.

Stream order	V
Length (km)	1.52
Elevation:	
Maximum (m)	2,124
Minimum (m)	2,111
Drainage Size (hectares)	26,805
Stream type[a]	B1

Habitat features	1988	1989	1989	1990	1991
Sample date	10/24	7/20	10/3	8/20	7/30
Time	1045	945	1400	1400	1100
Water column:					
Flow (m^3/s)	2.158	2.928	2.997	3.202	2.989
Channel width (m)	19.3	22.5	18.4	18.7	22.6
Stream width (m)	17.1	17.3	16.9	17.2	17.2
Stream depth (cm)	20	25	23	27	26
Stream shore water depth (cm)	6	0	0	5	0
Riffle width (m)	10.2	10.9	12.0	13.2	10.3
Pools:					
Width (m)	2.3	1.9	2.1	1.2	1.88
Quality	2.2	2.2	2.2	2.3	2.1
Feature[b]	1,4	4,1	4,1	1,4	4,1
Solar angle (°)	63.3	74.0	75.3	76.0	79
Channel morphology					
Streambank alteration (%)	23.3	26.7	20.8	25.8	26.7
Vegetative stability	3.5	3.3	3.5	3.5	3.8
Undercut (cm)	7	2	4	4	5
Channel-bank angle (°)	112.5	98.3	118.3	119.2	104.0
Stream bottom:					
Gradient (%)	3.9	1.4	2.1	3.2	3.2
Sinuosity	1.33	1.28	1.30	1.19	1.34
Substrate:					
Bedrock	56.0	58.8	55.3	60.7	53.5
Boulder (>305 mm)	10.2	8.9	4.0	8.0	11.9
Cobble (64-305 mm)	13.1	17.9	7.6	13.8	11.6
Gravel (2-64 mm)	2.4	2.6	1.6	4.4	7.5
Sand (0.6-2 mm)	13.6	9.5	24.0	7.2	11.3
Silt (<0.6 mm)	4.2	2.4	7.8	6.0	4.1
Embeddedness (%)	70.0	21.7	21.7	20.0	18.3
Channel vegetative cover (cm)	131	91	48	138	95
Riparian zone:					
Streamside cover type	2.0	1.8	1.8	1.8	1.8
Vegetative use (%)	9.2	6.7	16.7	6.7	3.3
Vegetation overhang (cm)	0.6	7	19	15	8
Habitat type	18,9	12,13	12,9	12,14	12,8

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[a] After Rosgen (1985).

[b] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

TABLE 30.-Drainage basin characteristics and habitat features of the Barns area of the Madison River, 1988-1991.

Stream order	VI
Length (km)	3.52
Elevation:	
Maximum (m)	2,017
Minimum (m)	2,004
Drainage Size (hectares)	111,214
Stream Type	C2

Habitat features	1988	1989	1990	1991
Sample date	11/3	8/31	9/27	10/10
Time	1100	1100	0915	1000
Water column:				
Flow (m^3/s)	9.17	11.79	12.44	10.41
Channel width (m)	52.9	52.8	49.2	53.1
Stream width (m)	51.4	51.5	47.8	51.2
Stream depth (cm)	28	35	36	34
Stream shore water depth (cm)	5	3	7	4
Riffle width (m)	39.0	42.5	37.8	38.1
Pools:				
Width (m)	3.1	3.4	4.1	4.9
Quality	1.5	1.4	2.6	1.7
Feature	3,6	3,2	3	3,4
Solar angle (°)	149	152	158	150
Channel morphology				
Streambank alteration (%)	21.7	23.3	25.8	39.2
Vegetative stability	3.0	3.5	2.8	3.3
Undercut (cm)	2	6	7	6
Channel-bank angle (°)	128	112	94	101
Stream bottom:				
Gradient (%)	0.3	0.6	1.0	1.0
Sinuosity	1.2	1.2	1.3	1.3
Substrate:				
Bedrock				
Boulder (> 305 mm)	2.8	3.4	12.7	6.1
Cobble (64-305 mm)	74.5	58.7	63.3	56.2
Gravel (2-64 mm)	5.7	17.7	15.0	12.1
Sand (0.6-2 mm)	11.6	19.0	8.4	24.9
Silt (< 0.6 mm)	5.3	1.3	0.7	0.8
Embeddedness (%)	42	13	50	22
Channel vegetative cover (cm)	549	518	1,049	784
Riparian zone:				
Streamside cover type	1.5	1.8	2.0	1.8
Vegetative use (%)	13.3	12	13.3	9.2
Vegetation overhang (cm)	0	7	14	4
Habitat type	8,13	8,15	12,9	8,13

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[a] After Rosgen (1985).

[b] 1 = log, tree, root, stump, brush, or debris; 2 = channel meander; 3 = rubble or gravel; 4 = boulder or bedrock; 5 = stream channel; 6 = fine sediments; 7 = streambank.

cobble, boulder, and bedrock. Riparian streamside cover type varied between bare ground (cover type 1) and grass (cover type 2), and some upland and riparian understory areas were generally covered with a layer of ash up to several centimeters (cm) deep. Because streambank vegetation was short or burned in the study reaches, there was only a small amount (< 3 cm) of overhanging streambank vegetation at the transect sites.

Between 1988 and 1991, stream discharge and width varied little at the study sites, but mean stream depth increased with higher streamflows (Tables 28-30). Estimated streambank alteration (percent eroded) was unchanged among sample dates in the Gibbon River, but increased in the other two streams to almost 40% by 1991. Trends in average size of undercuts (width and depth) were similar to those noted for streambank erosion. Gibbon River and Madison River sites maintained a riffle-width pool-width ratio of 10:1 among sample dates, but the trend was variable in the Firehole River. Solar angle (a measure of the potential amount of sunlight reaching the stream channel) changed little among sample dates in the Madison River and the Firehole River; in the Gibbon River, however, solar angle gradually increased as dead burned trees fell and streamside canopy decreased (Table 29).

Postfire substrate composition varied considerably at all Madison River watershed sites, but none of the changes were significant ($P > 0.25$). In the Firehole River, the proportion of silt in the stream bottom nearly doubled between 1988 and 1989. During the next 2 years, the proportion of silt decreased but remained above 25%. In the Gibbon River and Madison River, silt was a minor substrate component on all sample dates. In August 1989, a landslide composed primarily of fine materials occurred approximately 3 km upstream from the Gibbon River study sites. In the post-landslide survey (October 1989), the proportion of coarse sand in the Gibbon River substrate increased to nearly 25%, and declined the following year to prefire levels (Table 29). In the Madison River, proportion of sand generally increased between 1988 and 1991 (Table 30). In the latter surveys, some of the finer substrates in the Madison River were visually similar to Lava Creek tuff observed at the Gibbon River sites upstream. These results suggested that the moderate-gradient Gibbon River rapidly transports sediment through the study reach, and a portion of this sediment load is deposited in lower-gradient sections of the Madison River.

Channel vegetative cover (primarily aquatic macrophytes) more than doubled between 1988 and 1990 in the Firehole River and the Madison River (Tables 28 and 30). In the Gibbon River, however, amount of instream vegetation cover was similar to or less than that observed in 1988 on all survey dates. A large proportion of the vegetative cover in the Gibbon River in 1988 consisted of downed trees or debris jams which were displaced during subsequent peak streamflows. In addition, the influx of sand from the landslide may have scoured rooted vegetation. At all three study reaches in the Madison River drainage, revegetation of burned riparian areas was rapid. Overhanging grasses on streambanks were nearly 20 cm tall after 1 year of growth at transect sites in the Firehole River and Gibbon River.

Chemical Characteristics

Lamar River watershed.-All three streams in the Lamar River watershed were classified as calcium-bicarbonate streams during the postfire study. From 1989 to 1991, total dissolved solids (TDS) concentration declined in Slough Creek, but was relatively stable in Soda Butte Creek and the Lamar River (Tables 31-33). Total alkalinity and bicarbonate concentrations increased slightly or were unchanged between 1989 and 1990 in Slough Creek, then decreased considerably in 1991. The opposite trend for these two chemical components was observed in Soda Butte Creek and the Lamar River. Total hardness, calcium, magnesium, and silica increased at all three study sites between 1989 and 1991. Sulfate was one of the most variable elements analysed, and decreased in Slough Creek, increased in Soda Butte Creek, and showed no apparent trend in the Lamar River from 1989 to 1991.

In comparison to other postfire (burned and unburned sites) calcium-bicarbonate water chemistry samples from Yellowstone Park streams ($N = 43$), TDS concentrations in Soda Butte Creek and the Lamar River were in the 50th percentile of observed values. Although the fall 1989 TDS concentration in Slough Creek was one of the highest postfire values (rank, 6th), the decreased TDS concentrations in 1990 and 1991 were below the median postfire value for calcium-bicarbonate streams. Total alkalinity concentrations in Slough Creek and Lamar River were in the low to mid-range of ranked values (12th-31th) of postfire sites; however, alkalinity concentrations in Soda Butte Creek were among the highest recorded for postfire calcium-bicarbonate streams (ranks, 4th, 5th, and 8th). Sulfate concentration also spanned a broad range of ranks (10th in Lamar River to 31st in Slough Creek) in comparison to other postfire sites.

Water chemistry analyses are available for 158 calcium-bicarbonate water samples collected from streams throughout Yellowstone Park prior to the 1988 fire activity. With the exception of the 1991 Slough Creek sample, postfire TDS concentrations from the Lamar River watershed ranked in the top third of the parkwide prefire calcium-bicarbonate streams. Postfire total alkalinity concentrations encompassed a broad range of values but all were in at least the 50th percentile of prefire parkwide calcium-bicarbonate stream ranks. A similar postfire pattern was observed in sulfate concentrations at the Lamar River watershed study sites. All postfire sulfate concentrations were ranked higher than the prefire median value of 3.1 mg/L, but only the 1989 Lamar River sample was similar to the average prefire sulfate concentration for calcium-bicarbonate

TABLE 31.-Results of chemical analysis of water samples taken from first meadow section of Slough Creek, 1989 to 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

Slough Creek First Meadow			
DATE	8/1/89	8/08/90	8/20/91
STREAM TYPE	$CA-HCO_3$	$CA-HCO_3$	$CA-HCO_3$
TDS	160	98	68
CONDUCTIVITY	160	140	195
pH	8.4	7.2	8
P ALKALINITY	0	2.2	1.9
T ALKALINITY	71	92	58.8
CO_3	0	4.4	1.9
HCO_3	87	88	58.8
CL	0.99	0.99	0.99
SO_4	5.7	4.9	3.37
FL	0.09	0.09	0.09
COLOR	*	4.99	4.9
TURBIDITY	10	1.7	3.6
T HARDNESS	72.7	89	85
CA HARDNESS	49.4	61	57
CA	19.8	25	23
MG	5.66	6.9	6.9
NA	3.71	3.9	2.4
FE	0.099	0.12	0.099
MN	0.049	0.049	0.029
CU	0.015	0.018	0.009
SI	15	17	13.7
K	1.3	1.5	1.4
WATER TEMP	17.2	15.6	14.4

*-parameter not measured.

TABLE 32.-Results of chemical analysis of water samples taken from footbridge section of Soda Butte Creek, 1988 to 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

	Soda Butte Creek Footbridge			
DATE	8/13/88	8/18/89	9/27/90	9/6/91
STREAM TYPE	CA-HCO_3	CA-HCO_3	CA-HCO_3	CA-HCO_3
TDS	40	130	150	142
CONDUCTIVITY	*	250	230	260
pH	8.0	8.4	7.62	7.3
P ALKALINITY	7.7	0	1.9	1.9
T ALKALINITY	42	100	130	132
CO_3	9.2	0	0.49	1.9
HCO_3	51	120	130	132
CL	0.9	0.9	0.9	0.9
SO_4	3	5.5	5.9	6.8
FL	0.09	0.09	0.09	0.09
COLOR	4	30	4.9	4.9
TURBIDITY	3.3	1.1	0.31	0.7
T HARDNESS	85.7	112	139	144
CA HARDNESS	58.9	71.9	91	91
CA	23.6	28.8	35	36
MG	6.5	9.74	12	13
NA	2.43	3.9	4.3	4.4
FE	0.09	0.143	0.2	0.099
MN	0.049	0.049	0.049	0.029
CU	0.009	0.009	0.009	0.009
SI	11	35	17	20.1
K	1.79	1.73	2.1	2.2
WATER TEMP	16.7	8.9	8.3	15.6

*-parameter not measured.

TABLE 33.-Results of chemical analysis of water samples taken from of Lamar River picnic area, 1989 to 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

Lamar River Picnic Area			
DATE	9/7/89	9/27/90	9/5/91
STREAM TYPE	CA-HCO_3	CA-HCO_3	CA-HCO_3
TDS	110	130	106
CONDUCTIVITY	125	*	210
pH	8.1	7.86	7.8
P ALKALINITY	1.9	1.99	1.9
T ALKALINITY	55	90	97.3
CO_3	2.39	0.49	1.9
HCO_3	67	90	97.3
CL	0.9	0.99	0.9
SO_4	12	6.1	8.71
FL	0.1	0.49	0.17
COLOR	5	5.0	4.9
TURBIDITY	1.7	0.9	2.1
T HARDNESS	76.1	77	90
CA HARDNESS	47.9	49	55
CA	19.2	19	22
MG	6.85	6.9	8.4
NA	11.6	12	12
FE	0.218	0.38	0.26
MN	0.049	0.049	0.03
CU	0.018	0.009	0.009
SI	2.7	21	21.6
K	0.99	0.99	1.7
WATER TEMP	10.6	11.7	11.7

*-parameter not measured.

waters (12.45 mg/L). Postfire total hardness results from the Lamar River drainage streams were ranked in the 60th percentile of prefire concentrations, and all samples (except 1989 Slough Creek) were above the prefire calcium-bicarbonate mean (73.9 mg/L). Although the above results exhibit a large degree of variability, our data suggest that postfire concentrations of TDS, alkalinity, sulfate, and total hardness were elevated compared to prefire water chemistry analyses at the Lamar River watershed study sites.

Madison River watershed.-The Firehole River and the Madison River were classified as sodium-bicarbonate streams during the postfire study, and the Gibbon River was the only sodium-chloride stream surveyed. Values for TDS in these streams were considerably higher on all sample dates than the concentrations observed in the Lamar River drainage (Tables 34-36). Between 1989 and 1991, TDS increased in the Firehole River and the Madison River, but no apparent trend was observed in the Gibbon River. Total alkalinity and bicarbonate values in the Firehole River and the Gibbon River were similar to those in Slough Creek and the Lamar River; the elevated alkalinity and bicarbonate concentrations in the Madison River, however, were most similar to Soda Butte Creek. Sulfate concentrations in the Firehole River were similar to those from Slough Creek and Soda Butte Creek. The highest sulfate concentrations were in the Gibbon River. All postfire water samples from the Madison River drainage were classified as "soft" because total hardness concentrations were < 60 mg/L (Hem 1985).

Trends in the concentrations of most chemical constituents were variable in the streams of the Madison River watershed; however, examination of silica concentrations suggests a temporal pattern within the drainage. In the Gibbon River, silica concentrations exhibited a steady decline over the 3-year study period (Table 35). In the Madison River, the August 1990 sample yielded the highest silica concentration to date among our analyses of Yellowstone Park streams (N = 378 samples). The 1991 silica concentration is the 6th highest on record. Although the cause of the elevated silica concentration is unknown, both of these samples were collected after several large-scale landslides occurred upstream in the Gibbon River (summer 1989). These results suggest that the elevated silica concentrations in the Madison River may be related to a large amount of fine material moving through the system.

In comparison to postfire sodium-bicarbonate water samples (N = 30), postfire TDS concentrations in all Madison River watershed samples (except 1989 Firehole River) were in the upper third of observed values. Total alkalinity, bicarbonate, and sulfate concentrations in the Madison River also ranked in the upper third, but the concentrations noted in the Firehole River were ranked in the lower half of observed values. Sulfate

TABLE 34.-Results of chemical analysis of water samples taken from Firehole River Biscuit Basin, 1988 to 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

Firehole River Biscuit Basin				
DATE	6/14/88	9/27/89	8/2/90	10/4/91
STREAM TYPE	NA + K-HCO_3	NA + K-HCO_3	NA + K-HCO_3	NA + K-HCO_3
TDS	220	170	240	228
CONDUCTIVITY	*	300	300	300
pH	*	8.47	8.04	7.9
P ALKALINITY	1.9	1.9	1.99	1.9
T ALKALINITY	58	67	78	71.6
CO_3	2.3	2.39	1.99	1.9
HCO_3	71	82	78	71.6
CL	32	36	39	38.8
SO_4	*	4.7	5.7	5.49
FL	4.9	2.1	4.9	5.79
COLOR	4.9	5	4.9	4.9
TURBIDITY	0.9	0.99	0.99	0.49
T HARDNESS	12.7	10.7	14	13.2
CA HARDNESS	8.59	10.7	14	11.3
CA	3.44	4.29	5.5	4.5
MG	0.9	0.99	0.99	0.99
NA	43	52.9	60	55
FE	0.09	0.148	0.11	0.099
MN	0.049	0.049	0.049	0.029
CU	0.009	0.022	0.011	0.009
SI	86	96	87	92.1
K	4.81	2.81	5.2	6.2
WATER TEMP	18.9	21.7	17.8	12.8

*-parameter not measured.

TABLE 35.-Results of chemical analysis of water samples taken from Gibbon River at Canyon Creek, 1989 to 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

Gibbon River at Canyon Creek			
DATE	10/3/89	8/02/90	7/30/91
STREAM TYPE	NA + K-CL	NA + K-CL	NA + K-CL
TDS	240	260	212
CONDUCTIVITY	400	300	205
pH	8.0	7.5	7.5
P ALKALINITY	1.99	1.99	1.9
T ALKALINITY	67	65	55.7
CO_3	2.39	1.99	1.9
HCO_3	82	65	55.7
CL	52	49	34.2
SO_4	40	26	19.1
FL	1.3	2.7	3.19
COLOR	20	5	10
TURBIDITY	3.6	1.6	2.25
T HARDNESS	28.7	30	27
CA HARDNESS	22.9	24	21
CA	9.16	9.6	8.6
MG	1.41	1.5	1.5
NA	61.6	57	44
FE	0.582	0.55	0.35
MN	0.114	0.064	0.069
CU	0.015	0.017	0.009
SI	94	83	69.5
WATER TEMP	13.3	20.8	17.2

TABLE 36.-Results of chemical analysis of water samples taken from the Barns section of the Madison River, 1985, 1989, 1990, and 1991. Conductivity reported in µmhos/cm, pH in pH units, turbidity as NTU's, and water temperature in °C. Other values expressed as mg/L.

Madison River - Barns Section				
DATE	10/3/85	7/19/89	8/1/90	10/10/91
STREAM TYPE	NA + K-HCO_3	NA + K-HCO_3	NA + K-HCO_3	NA + K-HCO_3
TDS	260	250	350	330
CONDUCTIVITY	*	430	450	500
pH	*	8.3	8.13	7.2
P ALKALINITY	0	0	1.99	1.9
T ALKALINITY	109	100	120	119
CO_3	0	0	1.99	1.9
HCO_3	133	120	120	119
CL	51.8	54	58	60.2
SO_4	15.9	13	16	15.8
FL	6.84	6.2	5.9	7.06
COLOR	5	*	10	4.9
TURBIDITY	0.5	*	0.99	0.72
T HARDNESS	16.69	15.8	21	20.4
CA HARDNESS	12.6	15.8	21	17.1
CA	5.05	6.33	8.2	6.8
MG	0.09	0.99	0.99	0.99
NA	77.2	79.4	88	91
FE	0.14	0.13	0.2	0.099
MN	0.049	0.49	0.049	0.029
CU	0.009	0.011	0.014	0.009
SI	25.4	*	190	95.7
K	8.7	5.9	8	8.8
WATER TEMP	*	19	17.2	10

*-parameter not measured.

concentrations in the Gibbon River were ranked 8th, 10th, and 14th in comparison to all postfire analyses (*N* = 91).

Between 1989 and 1991, alkalinity, hardness, sodium, and silica increased in the Firehole River, above the prefire (June 1988) concentrations, but most other elements were similar to prefire data (Table 34). In the Madison River, only sulfates and potassium were similar to the prefire sample (October 1985), and most other chemical components were elevated in comparison to the prefire data (Table 36). In comparison to other sodium-bicarbonate water analyses collected prior to the fires (*N* = 89), TDS, alkalinity, bicarbonates, and sulfates from the three Madison River drainage postfire study reaches were all ranked in the upper third of prefire observations.

Macroinvertebrates

Detailed results of the macroinvertebrate collections from the postfire study sites are contained in reports by Mangum (1990, 1992) and Minshall et al. (1991). The following discussion is based on data from those reports.

Lamar River watershed.-In fall 1988, macroinvertebrate abundance in the Lamar River watershed ranged from 8,500/m^2 in Slough Creek to nearly 40,000/m^2 at the Lamar River sites (Table 37). Ephemeroptera (*Ameletus* sp. and *Cinygmula* sp.) were the most abundant macroinvertebrates collected from Slough Creek, but chironomids comprised more than one-half of the estimated macroinvertebrate abundance in Soda Butte Creek and the Lamar River. Consequently, in the Lamar River, diversity index was low, although total number of species collected was similar to Slough Creek (Table 37). In Soda Butte Creek, large stoneflies (*Podmosta* and *Pteronarcella* sp.) ranked third and fourth, respectively, in frequency of occurrence and represented 13% of the sample. In 1988, Ephemeroptera had the highest species richness in Slough Creek and the Lamar River, but numbers of Plecoptera and Diptera taxa were nearly as great. Proportions of the various trophic groups were similar in the three study streams, but scrapers were less common in Soda Butte Creek and the Lamar River than in Slough Creek.

Between 1988 and 1990, trends in macroinvertebrate abundance were different in each of the Lamar River drainage streams (Table 37). Because Chironomidae was the dominant taxon in most samples, the observed postfire fluctuations in total macroinvertebrate abundance are probably related to annual variations in chironomid abundance. For example, in 1990, total macroinvertebrate abundance decreased to 1988 levels in Soda Butte Creek (Table 37). Abundance of *Brachycentrus* sp. in 1990 was relatively unchanged from 1989 (more than 2,500 individuals/m^2) and almost one-third as abundant as chironomids in 1990. In contrast, chironomids were a minor group in the 1989

TABLE 37.-Macroinvertebrate community characteristics from postfire study sites in Lamar River drainage. With the exception of 1988 Soda Butte Creek data, all values represent mean of three 0.09m^2 Surber sampler results. Soda Butte Creek (1988) is mean of five samples and represent five most abundant taxa (Minshall et al. 1991).

	1988	1989	1990
Slough Creek			
Abundance (#/m^2)	8468	1090	13873
Total # of species	30	20	34
DAT Diversity Index	9.6	8.6	10.2
Functional Feeding Groups			
% Shredders	6.6	2.0	4.7
% Collectors	71.3	64.3	71.7
% Scrapers	17.0	19.5	12.2
% Predators	5.0	14.2	11.4
Soda Butte Creek			
Abundance	17324	33715	14591
Total # species	5	28	27
DAT Diversity Index	N/A	5.4	10.6
Functional Feeding Groups			
% Shredders	7	0.6	3.6
% Collectors	72	86.2	80.0
% Scrapers	8	2.0	6.1
% Predators	13	11.2	10.8
Lamar River			
Abundance	39080	28119	16599
Total # species	28	32	32
DAT Diversity Index	4.7	9.3	20.7
Functional Feeding Groups			
% Shredders	7.6	8.1	9.8
% Collectors	78.7	78.0	65.1
% Scrapers	1.6	2.6	14.7
% Predators	12.1	10.9	10.3

Slough Creek sample, which had the lowest macroinvertebrate abundance of any Lamar River drainage sample. Species richness revealed little annual variation except in Slough Creek. Diversity index varied among years, but generally increased at all three sites between 1988 and 1990 (Table 37). Estimated macroinvertebrate biomass increased in the Lamar River and Slough Creek between 1988 and 1990, but decreased by approximately 50% from 1989 to 1990 in Soda Butte Creek as the proportion of chironomids declined (Mangum 1990, 1992).

Relative proportions of the different functional feeding groups varied little among years, although collectors tended to increase at Soda Butte Creek and decrease in the Lamar River during the course of the study. A decrease in abundance of herbivorous scrapers suggests a reduction in primary productivity at the Slough Creek study site; however, in 1990 in the Lamar River, the density of >1,500 glossosomatid caddisflies/m^2 indicated increased instream algal growth. Additionally, an abundance of shredder stoneflies is indicative of a stream with extensive input of riparian vegetation (Mangum 1990).

Many of the taxa collected from the Lamar River drainage are moderately tolerant of extensive changes (particularly sediment introductions) in the stream environment. A preponderance of these taxa suggests that environmental conditions in these streams are variable (Mangum 1990). Collection of numerous species that are adapted to a restricted range of environmental conditions, however, indicate improved aquatic habitat quality in these streams. Biotic Condition Indices for the Lamar River watershed sites suggested some variability among years in the suitability of the macroinvertebrate habitat. Slough Creek showed a decrease in BCI values that may indicate unstable substrate conditions. Lamar River BCI also decreased slightly from 1988 to 1990; however, the stream was rated as stable (Mangum 1990). In Soda Butte Creek, BCI increased between 1989 and 1990. This may indicate an improvement in macroinvertebrate habitat suitability in this stream.

Madison River watershed.-Abundance, species richness, and DAT diversity indices of macroinvertebrates in the fall 1988 samples from the Madison River watershed encompassed a range similar to collections from the Lamar River watershed (Tables 37 and 38). Among Madison River watershed sites, the Firehole River had the highest estimated macroinvertebrate abundance of approximately 39,000 individuals/m^2; members of the Class Ostracoda constituted the majority (density, 25,000/m^2) of this sample. Chironomids were the most abundant insects in the Firehole River and the Madison River. In contrast to the other five survey streams, in the Gibbon River, Trichoptera was the most diverse order (ten taxa) and included the most abundant taxon (Lepidostomatidae) in the fall 1988 samples.

TABLE 38.-Macroinvertebrate community characteristics from postfire study sites in Madison River drainage. All values represent mean of three $0.09 m^2$ Surber sampler results.

	1988	7/1989	10/1989	1990
Firehole River				
Abundance (#/m^2)	38633		14175	19052
Total # of species	29		19	16
DAT Diversity Index	7.9		6.1	7.0
Functional Feeding Groups				
% Shredders	2.1		3.4	0
% Collectors	82.5		77.1	34.5
% Scrapers	12.8		16.2	64.4
% Predators	2.6		3.3	1.0
Gibbon River				
Abundance	14404	5957	1230	6313
Total # species	30	25	26	26
DAT Diversity Index	14.6	8.9	12.1	9.3
Functional Feeding Groups				
% Shredders	19.9	7.1	1.6	0.7
% Collectors	69.1	81.3	79.8	67.2
% Scrapers	9.1	8.6	11.0	30.8
% Predators	2.0	3.1	7.6	1.3
Madison River				
Abundance	8913	14175		5950
Total # species	26	21		25
DAT Diversity Index	11.5	6.8		13.3
Functional Feeding Groups				
% Shredders	0.6	0.1		1.9
% Collectors	88.0	85.2		83.0
% Scrapers	5.8	6.4		10.7
% Predators	5.6	8.3		4.4

Proportions of trophic groups in the Firehole River and the Madison River in 1988 were similar to those in the fall 1988 Lamar River drainage, except the percentage of collectors was higher and the proportion of predators were lower in the Madison River watershed sites. The proportion of shredders in the Gibbon River (20%) was the highest of any site among all sample dates.

Between 1988 and 1990, variable patterns in estimated abundance were observed in the Madison River drainage streams (Table 38). Comparison of results among the 3 years of the postfire period, however, suggests that the community abundance is strongly influenced by the density of Ostracoda in the Firehole River and Chironomidae in the Madison River. Ephemeropterans, trichopterans, and Elmidae (riffle beetles) were the dominant groups affecting total abundance in our collections from the Gibbon River; however, the introduction of large amounts of sediment into the stream channel from the landslides in August 1989 may have affected macroinvertebrate community abundance between July and October 1989 (Table 38). In particular, numerous *Brachycentrus* sp. were observed attached to a piece of discarded fishing line in October 1989, but this taxon was under-represented in the Surber samples (density, 4 individuals/m^2). Similarly, *Simulium* sp. density decreased by a factor of 100 between July and October 1989 (Mangum 1990). These results suggest that the predominant substrate sizes associated with the landslides may have had a "scouring" effect or eliminated most suitable attachment sites for sessile or clinging taxa. In 1990, abundance of these two taxa was similar to or exceeded densities observed in July 1989. In contrast to the increased diversity noted in the Lamar River drainage, species richness and diversity index declined or varied little among Madison River watershed sites from 1988 to 1990 (Table 38).

Proportions of functional feeding groups varied extensively among years in the Madison River watershed. Although shredders were a minor trophic group in all samples of the Firehole River macroinvertebrate community (Table 38), the density of scrapers (primarily *Optioservus* sp.) increased to more than 9,000 individuals/m^2 by 1990 as the amount of instream vegetation available for herbivorous trophic groups increased (Table 38). The 1990 Firehole River sample was the only sample in which collectors were not the dominant trophic group (Tables 37 and 38). A similar, but less dramatic, trend occurred in the Gibbon River, as the proportion of shredders progressively declined throughout the postfire period (Table 38), and the proportion of herbivores (scrapers) exceeded 30% in fall 1990, indicating instream production of attached algae and diatoms adequate to support a density of 850 glossosomatid caddisflies/m^2. At the Madison River site, trophic groups varied little between 1988 and 1990.

Between 1988 and 1990, estimated macroinvertebrate biomass declined in the Firehole River, but varied in the Gibbon River and the Madison River, where 1988 and 1990 estimates were nearly identical. The range of estimated biomass values from the Madison River drainage were higher than those noted in Slough Creek, but only about half that in Soda Butte Creek and the Lamar River.

A decrease in BCI was observed in the Firehole River and the Gibbon River, but was unchanged in the Madison River between 1988 and 1990 (Mangum 1990, 1992). Most taxa from the Firehole River were tolerant of sediment or organic enrichment and few "clean water species" [taxa intolerant of varying environmental conditions and that generally only occur in unpolluted aquatic habitats (Mangum 1988)] were collected. In the Gibbon River, BCI value for the fall 1988 sample was among the highest reported from any of the six study streams; however, although some "clean water species" (e.g., *Deuterophlebia* sp.) occurred in the samples, the consistent decline in the BCI suggests that the Gibbon River currently does not provide suitable habitat conditions for some of the taxa present in 1988 (Mangum 1992). With the exception of the 1990 Slough Creek sample, estimated biomass and BCI of the macroinvertebrate community in the Madison River were lower than all other sample sites for all sample years (Mangum 1992). These results suggest that macroinvertebrate habitat in the streams of the Madison River drainage was highly variable between 1988 and 1990. Those taxa able to tolerant variable sediment inputs were most abundant during the postfire period.

Fish Populations

Logistic constraints prevented sampling of fish populations in each of the postfire study streams during each of the four years of the study (1988-1991). Consequently, within-stream comparisons of fish populations between prefire and postfire periods are limited. For most of the study streams, only general comments or comparisons with other studies can be made.

Lamar River watershed.-With the exception of 1985, the Soda Butte Creek habitat study reach has been electrofished annually since 1984, but unequal amounts of electrofishing effort tend to limit comparisons between prefire and postfire fish populations in the Lamar River. There has been no statistically significant difference between average number of fish caught by electrofishing in the prefire period (1984-1987) and the postfire study (1988-1991) in either Soda Butte Creek ($t = 0.93$, $P = 0.44$) or in the Lamar River study reach ($t = 1.05$, $P = 0.36$). Postfire mean length of captured trout in Soda Butte was nearly 13 mm longer than that of the prefire in the period, but the increase was not significant (t-test, $P = 0.10$). In the Lamar River, however, mean total length fluctuated by as much as 40 mm among years, but the average size of trout captured in the postfire period was insignificantly shorter (about 10 mm) than those captured prior to 1988 ($t = 0.67$, $P = 0.54$). From 1984 to 1987, approximately 5.5% of the trout in electrofishing samples from Soda Butte Creek were longer than 330 mm total length. In the postfire period the proportion of these large trout increased to 14%; the number of trout captured in this size group was similar among years in the Lamar River. Changes in angling regulations may be responsible for the increased number of larger fish (Jones et al. 1991); these results, however, suggest that fire impacts on the larger fish in these streams have been limited.

Estimated mean age of captured trout from Soda Butte Creek and the Lamar river was similar among prefire years, but declined slightly in succeeding years as more fish less than 150 mm in length were captured. In 1990, the most recent year that age data are available, three-year-old and four-year-old trout were the most common age groups in these two streams. These results indicate that recruitment in Soda Butte Creek and the Lamar River has been successful in recent years. Because the Soda Butte Creek drainage was only slightly affected by fire, postfire sediment processes may represent those occurring in the natural variability of the stream and do not appear to be adversely affecting the smaller fish. Similarly, electrofishing results from the Lamar River suggest a variable fish population, and specific effects attributable to fire activity are not readily apparent.

In Slough Creek, electrofishing was conducted shortly after cessation of fire activity (October 1988) and repeated 1 year later. Estimated abundance (number of fish/ha) increased by an order of magnitude between 1988 and 1989, but length ranges of the sampled populations were similar (Jones et al. 1990). Estimated biomass of trout increased between 1988 and 1989; mean age of the sampled populations declined, however, from 4.7 years in 1988 to 2.9 years in 1989 because numerous small fish were present in 1989 sample. Interestingly, the mean biomass from the 2 years of postfire study (45 kg/ha) was the same as the mean estimated biomass obtained by three different methods in 1980 (Jones et al. 1981). Jones et al. (1990) suggested that trout population data from Slough Creek may have been influenced more by differences in habitat availability and variable electrofishing effectiveness, than by possible effects of forest fires.

Madison River watershed.-Prior to 1988, extensive effort was devoted to the study of fish populations in the Firehole and Madison rivers, but postfire electrofishing effort was restricted to 1 (Madison River) or 2 (Firehole River) years of sampling. In the Gibbon River, with the exception of relative species abundance data from 1987, electrofishing effort has been restricted to postfire conditions.

In the recent surveys in the Biscuit Basin reach of the Firehole River, although trout abundance differed by a factor of four between 1987 and 1988, nearly equal proportions of brown trout and rainbow trout were captured by electrofishing in fall 1987 and 1988 (Jones et al. 1988, 1989). Following the first postfire runoff (spring 1989), the electrofishing sample contained more than 70% brown trout, which represented a significant change from previous samples (Koch 1990). Koch (1990) noted, however, that the length distributions of the populations were similar between years. Dynamics of the Firehole River trout populations are discussed in the report on the History of the Firehole River Fishery (this volume). Fish population data from the recent surveys appear to be within the long-term variation in the Firehole River.

A similar amount of long-term trout population variability was noted in the Barns area of the Madison River, where an average of 1,000 salmonids were captured during each electrofishing study between 1978 and 1987, and 925 salmonids were captured in the postfire sample (July 1989). Relative species abundance was similar between the prefire period (72% whitefish, 20% brown trout, and 7% rainbow trout) and the postfire sample (85%, 13%, and 3%, respectively). Examination of trends in mean total length for each species between the prefire period and the postfire sample showed variation among species: brown trout increased, rainbow trout exhibited a decrease in mean length, but mean length of whitefish was unchanged. The high degree of variability in techniques and results has made interpretation of electrofishing data particularly difficult in the Madison River and, in their initial postfire assessment of this stream, Jones et al. (1990) concluded that there appeared to be no evidence that indicated negative postfire impacts to the fish populations.

In 1987, a single electroshocking pass through the Gibbon River study reach yielded more than 100 salmonids (approximately 80% brown trout, 18% rainbow trout, and < 2% mountain whitefish and brook trout). The initial postfire sample in summer 1989 yielded similar results, except that rainbow trout and mountain whitefish were captured in almost equal proportions (Jones et al. 1991); in subsequent samples (October 1989 and August 1990), the relative proportion of brown trout decreased as rainbow trout abundance increased. Sediment inputs associated with landslide activity in August 1989 did not appear to have affected the smaller fish in the stream (Jones et al. 1991) because many small (<100 mm total length) trout were captured in October 1989 and August 1990.

Discussion

The 1988 fires undoubtedly caused some changes in the aquatic habitat of Yellowstone Park, but the greatest changes seem to have taken place in the smallest streams. Striking postfire effects were observed in first to fourth order streams, and a return to prefire conditions may be a long-term process (100+ years) (Minshall et al. 1989, 1991). A variety of complex factors functioning simultaneously define the stream environment of the large watersheds of the current postfire study. As a result, the influence of a particular factor (including fire) on a large stream may be difficult to understand or quantify. Data interpretation in the current study has been within this context.

Stream habitat.-Results from the current study have shown that the anticipated effects of the 1988 fires on erosion and sedimentation rates in these larger streams have not been severe. Cool spring weather during the postfire period (particularly in 1989) decreased the anticipated high rate of runoff and moderated potentially major changes to stream habitats and resident fish populations. With the exception of the bedrock channel in the Gibbon River, estimated streambank erosion generally increased; however, habitat transect data suggest that all six study streams maintained their normal degree of stability throughout the postfire period. We observed active bank erosion in the Lamar River as a section of high streambank approximately 1 m in width slumped into the stream channel between 1988 and 1990. By 1991, at the adjacent downstream transect site, peak-streamflow silt deposition enhanced reestablishment of streamside vegetation at several previously unvegetated sites. In the Firehole River, stream width decreased by 4 m at one transect, as fine sediments were deposited in a lateral channel and the previously eroded streambanks began to revegetate.

Changes in substrate composition in the six study streams appeared unrelated to the proportion of the watershed that burned. For example, substrate composition changed to a similar degree in Soda Butte Creek and Slough Creek, even though the difference in burned area between the two watersheds was 20,000 hectares.

In most of the study streams, instream vegetative cover for fish increased from 1988 to 1991. Riparian regrowth was most extensive in the intensely burned forest study areas. Streambank habitat ratings were unchanged or increased at all study sites; these trends indicate that all streams were generally stable under varying streamflows.

Chemical features.-Water chemistry data are often variable and affected by streamflow (Hem 1985). Data from the postfire study exemplify this variability, and definitive trends are potentially obscured by the extremely low prefire streamflows in 1988. Examination of the ranked data, however, revealed some consistent patterns. Total alkalinity, TDS, sulfate, and hardness generally increased in all streams (except the Gibbon River) between 1988 and 1991. In smaller streams, increases in chemical concentrations have been attributed to increased watershed discharge (Albin 1979; Stottlemeyer 1987). Larger streams should be relatively unaffected unless there are tributaries with extensively burned drainages near the sample sites (Minshall et al. 1989). Results from the current study suggest a postfire increase in chemical concentrations within the six study streams. Madison River watershed study sites had higher concentrations of numerous chemical elements than were found in the Lamar River watershed study reaches.

Macroinvertebrates.-Macroinvertebrate collection results can be influenced by time of collection, number of samples, and emergence and dispersal of various taxa. In a pattern similar to a common postfire response (Minshall and Brock 1991), aquatic insect abundance declined between 1988 and 1989 in four of the six study streams, and then subsequently increased; however, macroinvertebrate trophic structure was similar in all years in streams of the Lamar River drainage. Community-level changes similar to those occuring in small headwater streams (Minshall et al. 1991) were noted in the Firehole River and Gibbon River, possibly in response to the reestablishment of instream vegetation. As these river systems continue to respond to fire activity, abundance of aquatic insects may continue to increase as a result of nutrient input from the fires.

Fish.-Results of fish sampling revealed few changes in the populations during the postfire period, and there were no data to suggest extensive fire-related effects on these populations. Annual postfire fluctuations in the fish populations appear to be within the range observed prior to 1989. Information from anglers suggested that, in some of the study streams, landing rates were lower in the first year after the fires. A short-term increase in stream turbidity rather than an actual decline in the fish populations may have affected catch rates.

Observed postfire fish mortality in the study streams was restricted to a single small (110 mm TL) rainbow trout found at the Gibbon River site in October 1988. Additional fish mortality was observed during and after the 1988 fires in some of the smaller streams, including Cache Creek, Blacktail Deer Creek (Jones et al. 1990), and a tributary near the Cold Creek patrol cabin (Richard Jones, NPS Ranger, personal communication). Intense heat may have contributed to the fish mortality in many cases (Minshall et al. 1991); however, fire retardant was responsible for the mortality in the Little Firehole River (Jones et al. 1989). By summer 1989, fish populations had been reestablished in these streams.

Although a variety of changes apparently occurred within the postfire study streams, definitive conclusions cannot be made at this time. A significant portion of the data from the current study has not been analyzed for this report. Foremost of these are the 1991 macroinvertebrate samples, which have yet to be processed. Other constraints have delayed age and growth analyses of the 1991 fish populations. These additional data will be included in a forthcoming report. Because the postfire study streams have been relatively unaffected by anthropogenic activities, the primary utility of the current study may be to assist in defining a "new" baseline stream condition against which future studies can be measured.

WILDLIFE RESOURCES AND RECREATIONAL USE IN THE LEWIS RIVER CHANNEL DURING THE BROWN TROUT SPAWNING SEASON: 1991 UPDATE

Brown trout *Salmo trutta* spawn in the Lewis River Channel during fall and early winter. Resident and migratory birds that use the channel area during these seasons include ducks, trumpeter swans *Cygnus buccinator*, tundra swans *C. columbianus*, and bald eagles *Haliaeetus leucocephalas*. Grizzly bear *Ursus arctos horribilis*, black bear *U. americanus*, mule deer *Odocoileus hemionus*, elk *Cervus elaphus*, and moose *Alces alces* have also been observed.

Popular recreational activities in the Lewis River Channel area during fall and early winter include angling, hiking, and nonmotorized boating. Park managers are concerned that angling and boating may negatively affect brown trout spawning success or disturb and displace eagles and swans. Consequently, the National Park Service (NPS) and U.S. Fish and Wildlife Service are attempting to evaluate the influence of recreational activities on wildlife resources in the Lewis River Channel area during the brown trout spawning season (September to November). Objectives are to determine the:

1) timing of brown trout spawning and distribution of brown trout spawners in the channel;
2) abundance and distribution of eagles and swans;
3) extent of bear activity;
4) extent and patterns of angler use; and
5) extent and patterns of boat use.

Study Area

The Lewis River Channel lies in south-central Yellowstone National Park and flows south from Shoshone Lake to Lewis Lake (Figure 49); the channel is 5 km long and has an average gradient of 0.05%. Reach 1 extends from Lewis Lake upstream 1.7 km to Point of Rocks and is characterized by relatively deep, slow-moving water. Reach 2 begins at Point of Rocks and extends upstream for 1.4 km; water depth and velocity in Reach 2 are slightly shallower and faster than in Reach 1, and *Elodea* sp. beds are abundant near Harvey's Point. Reach 3, the upper 1.8 km of the channel, is characterized by shallow, rapidly moving water and a gravel substrate; most of the 3.3-m drop in elevation between Shoshone and Lewis lakes and most of the brown trout spawning occur here.

Visitors access the channel by boat, foot, or horseback. Boaters motor or paddle across Lewis Lake and then paddle up the channel (a total distance of about 8 km); boaters paddling up the channel to Shoshone Lake must drag their boats through most of Reach 3 because of the shallow, rapid water. Hikers and horse

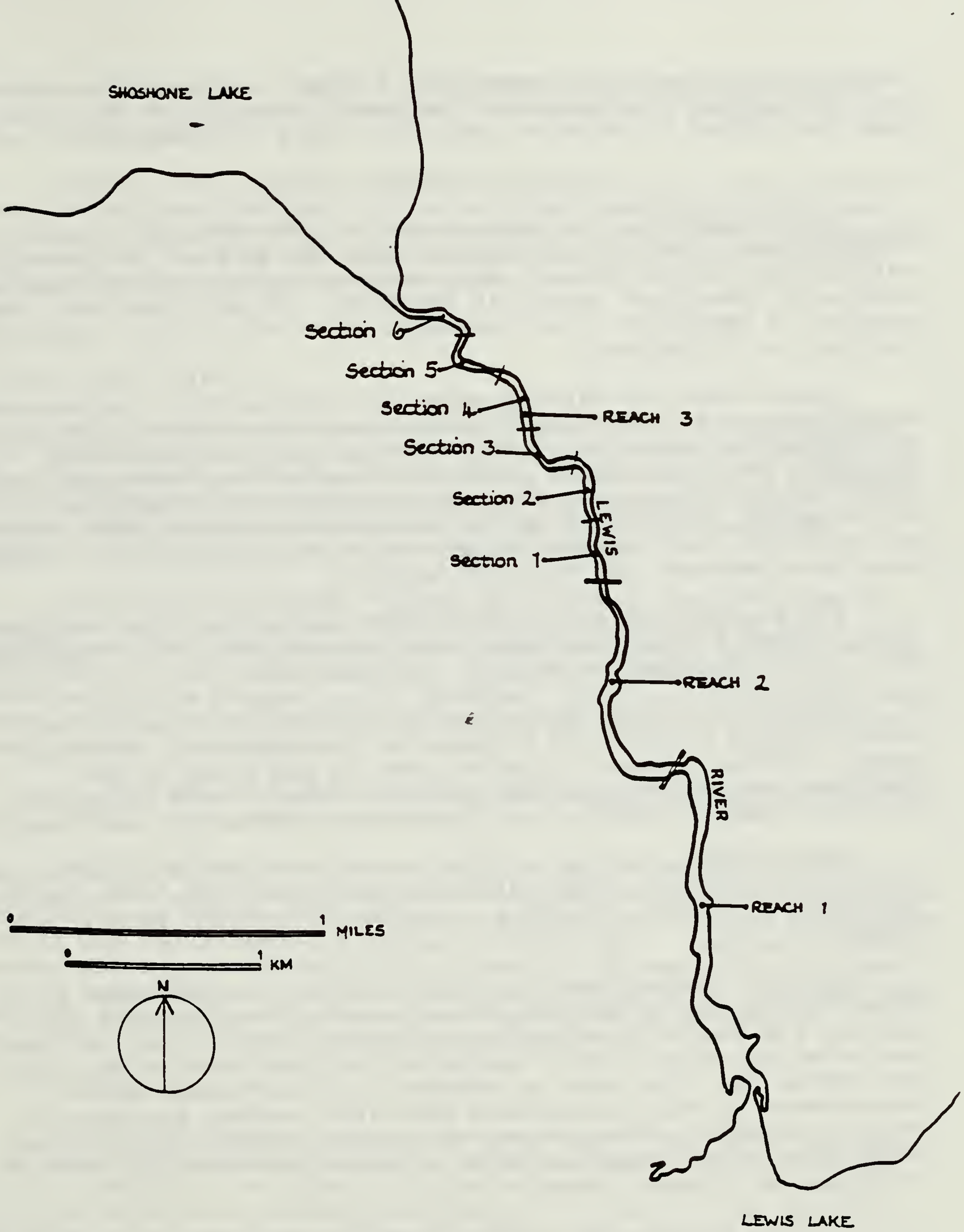

FIGURE 49.-Lewis River Channel, showing reaches and sections.

parties can access the channel via a 19-km loop trail that starts and ends at the Shoshone Lake trailhead. Camping is available near the outlet of Shoshone Lake for hikers and boaters.

Methods

Study duration.-The study began in 1990 and will extend through 1993. During the past 2 years, the NPS did not restrict visitor use in the channel area, and the fishing season remained open until the first Sunday in November. In 1992 and 1993, the channel is scheduled to be closed to all visitor use, including angling, on 15 October.

Brown trout.-In mid-September of 1990 and 1991, twice-weekly visual checks for adult-size brown trout were made in the channel to detect the beginning of the spawning run. Once spawning started, visual counts of adult-size brown trout were made weekly until the spawning run ended. To determine the longitudinal distribution of spawners in the channel, Reach 3 was divided into six sections, each approximately 300 m long (Figure 49). Counts were made between 1000 and 1500 hours.

The thermograph installed in 1990 was replaced on 7 August 1991. Water temperature data from 1990 and 1991 will be analyzed when the thermograph is removed in summer 1992.

Eagles and swans.-Eagle and swan surveys were conducted weekly during October and November of 1990 and 1991. Surveys began in Reach 1 about 1 h after sunrise and ended at the Shoshone Lake outlet approximately 3 h later. Data collected included number, species, and distribution of eagles and swans.

Bears.-While conducting fish counts, observers recorded bear sign (e.g., tracks, scats, fish carcasses and other evidence of predation on trout) according to methods described in Reinhart (1988).

Angling.-Manned creel surveys, similar to those made by the USFWS in 1971 and 1976 (Jones et al. 1977), were used to study angling and sample creeled fish in 1990 and 1991. Surveys were conducted twice each week, beginning the last week of September and ending the first week of November. Survey dates were established by stratifying each week into weekday and weekend periods; weekday survey dates were chosen randomly, and weekend dates were chosen using a random start and alternating between Saturday and Sunday.

On each survey date, counts of anglers were made in the morning and afternoon, alternating between upstream and downstream directions. Morning counts began at approximately 1100 hours, and afternoon counts started at approximately 1400 hours. Between counts, anglers were interviewed to determine length of time spent fishing and species and number of fish landed and creeled. Lengths, weights, and scale samples were taken from creeled fish; however, no age-growth analyses have yet been completed.

Boating.-The number of boats traveling to and from Shoshone Lake during the 1990 and 1991 brown trout spawning seasons was determined from NPS backcountry permits. Each "boat" represented an overnight trip up and down the channel; no attempt has yet been made to quantify day "boat" use.

Results

Current Year (1991)

Brown trout spawners were first observed on 26 September, and the highest spawner count occurred on 16 October (Figure 50). Spawning probably continued beyond the last count on 7 November, and it is estimated that the spawning run lasted at least 7 weeks. Most spawners were found in Section 5, followed by Section 3 and Section 6 (Figure 51).

The most bald eagles sighted in a single day was three on 3 October and 7 November (Figure 50). Trends in bald eagle abundance closely followed those for brown trout, except for the observation made on 7 November. Trumpeter swans were first observed on the channel on 31 October. Only two swan counts were made in 1991; 10 swans were observed on 31 October and 16 swans were seen on 7 November.

No bear activity was observed in the channel area during the 1991 brown trout spawning season.

Estimated total angler effort and mean landing rate were 1,629 h and 0.83 fish/h. Of an estimated 1,043 trout landed, 98% were released (Table 39). Highest angler use occurred during the second and third weeks of October (Figure 52). Angling virtually ceased after a snowstorm on 23 October; only one group of three people was observed in the channel after this date. Highest boat use (28 overnight trips) occurred during the last week of September and declined thereafter (Figure 52).

Two-Year Trends (1990-1991)

During the past 2 years, the brown trout spawning runs in the Lewis River Channel began in late September, peaked in mid-to-late October, and ended in late November or early December. Most spawners were found in Sections 3, 5, and 6. Estimates of incubation and emergence times for brown trout eggs and fry will be made when temperature data are analyzed.

Bald eagles arrived in the channel area in early-to-mid October of 1990 and 1991; they may be attracted to the spawning trout, which are vulnerable to predation in shallow sections of

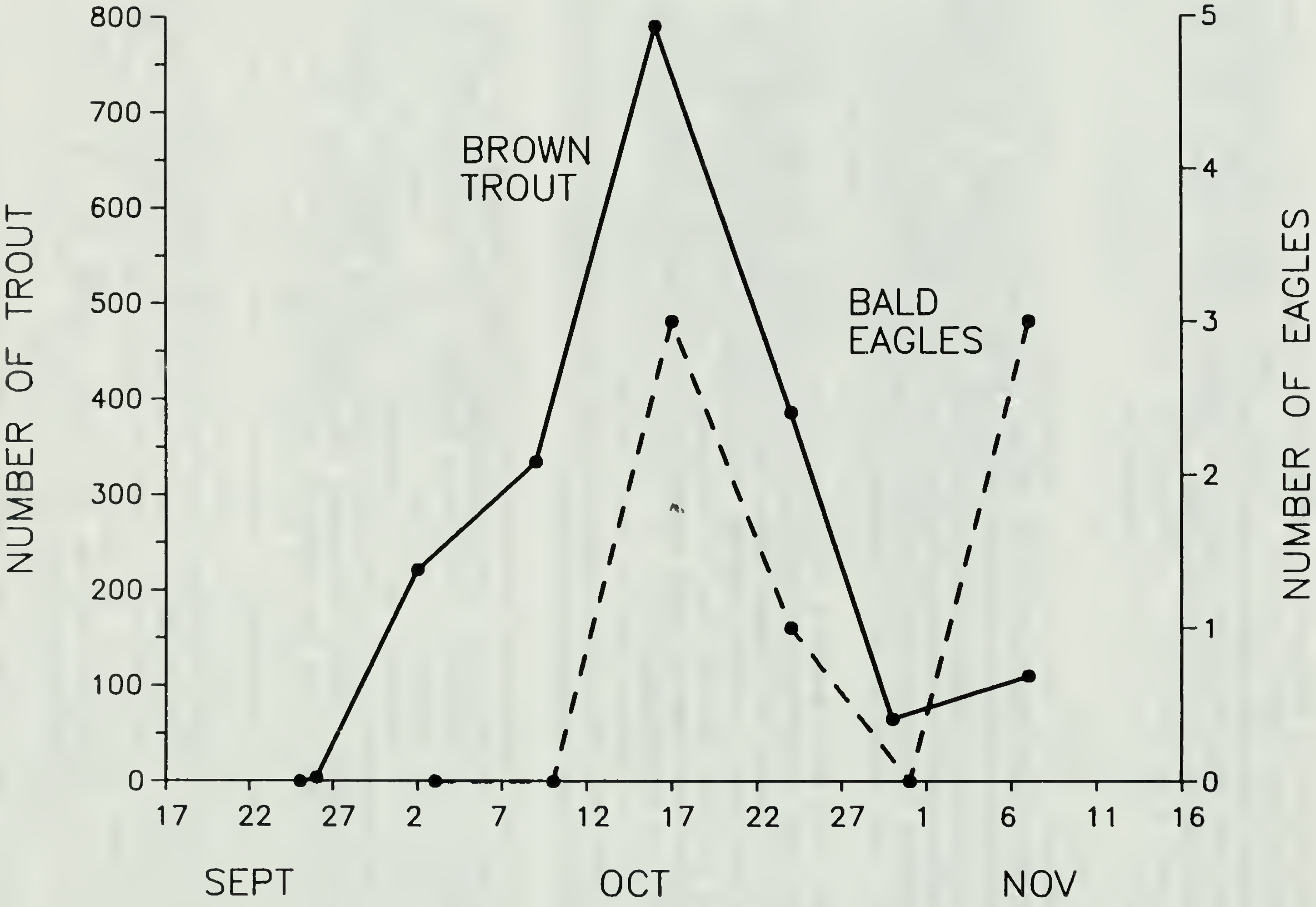

FIGURE 50.-Counts of brown trout spawners and bald eagles in the Lewis River Channel, 1991.

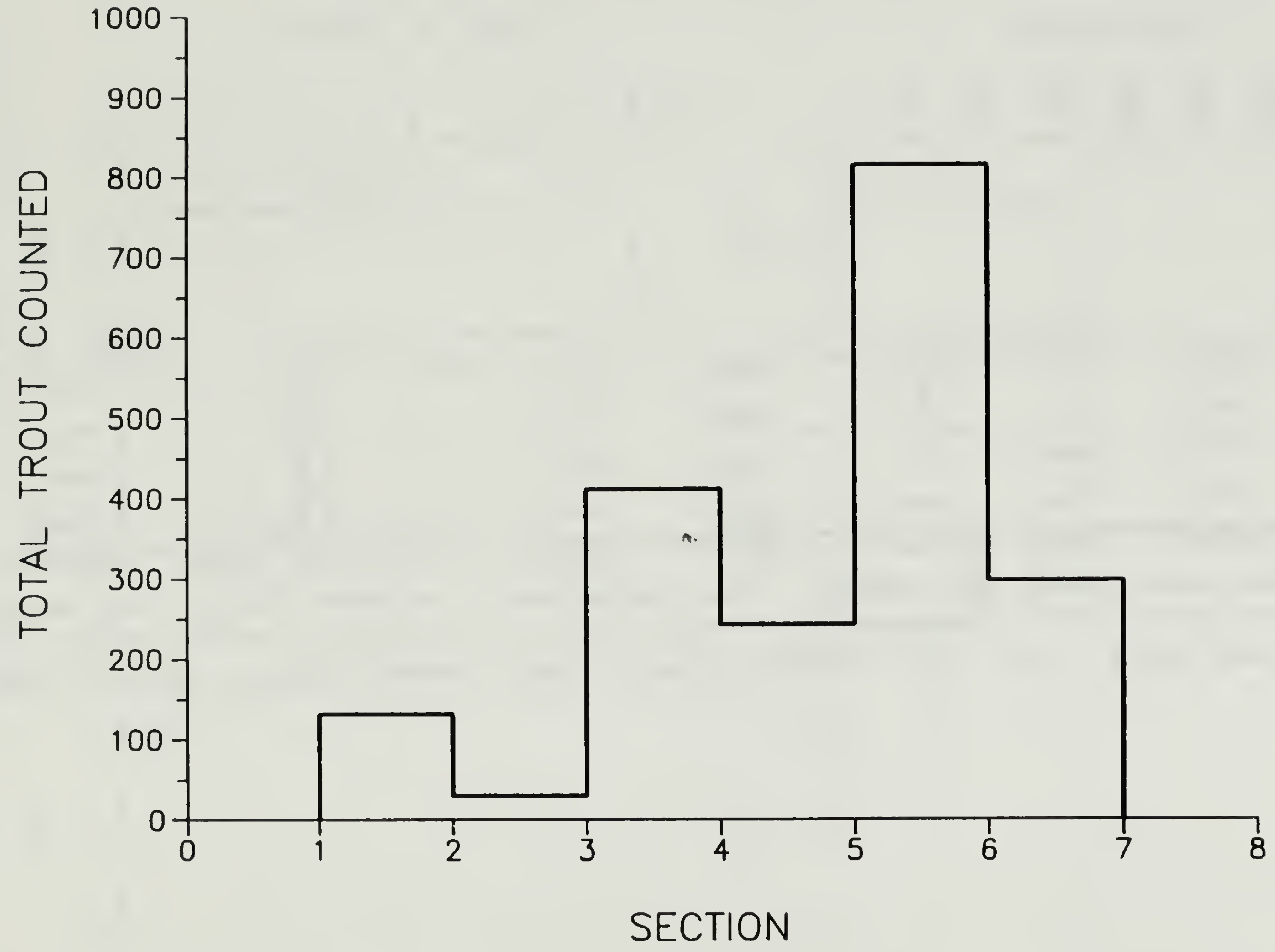

FIGURE 51.-Distribution of brown trout spawners in the Lewis River Channel, 1991.

TABLE 39.-Lewis River Channel creel survey results, 1971, 1976, 1990, and 1991.

Year	Angler days (# trips)	Average length of angler day (hours)	Total effort (hours)	Trout landed	Landing rate (fish/h)	Trout kept	Creel rate (fish/h)	Fish released (%)
1971[a]	413	3.8	1,568	1,537	0.98	643	0.41	58
1976[a]	689	2.7	1,847	2,992	1.62	388	0.21	87
1990	305	2.9	833	1,067	1.13	67	0.08	93
1991	716	2.8	1,629	1,043	0.83	25	0.02	98

[a] Jones et al. (1977).

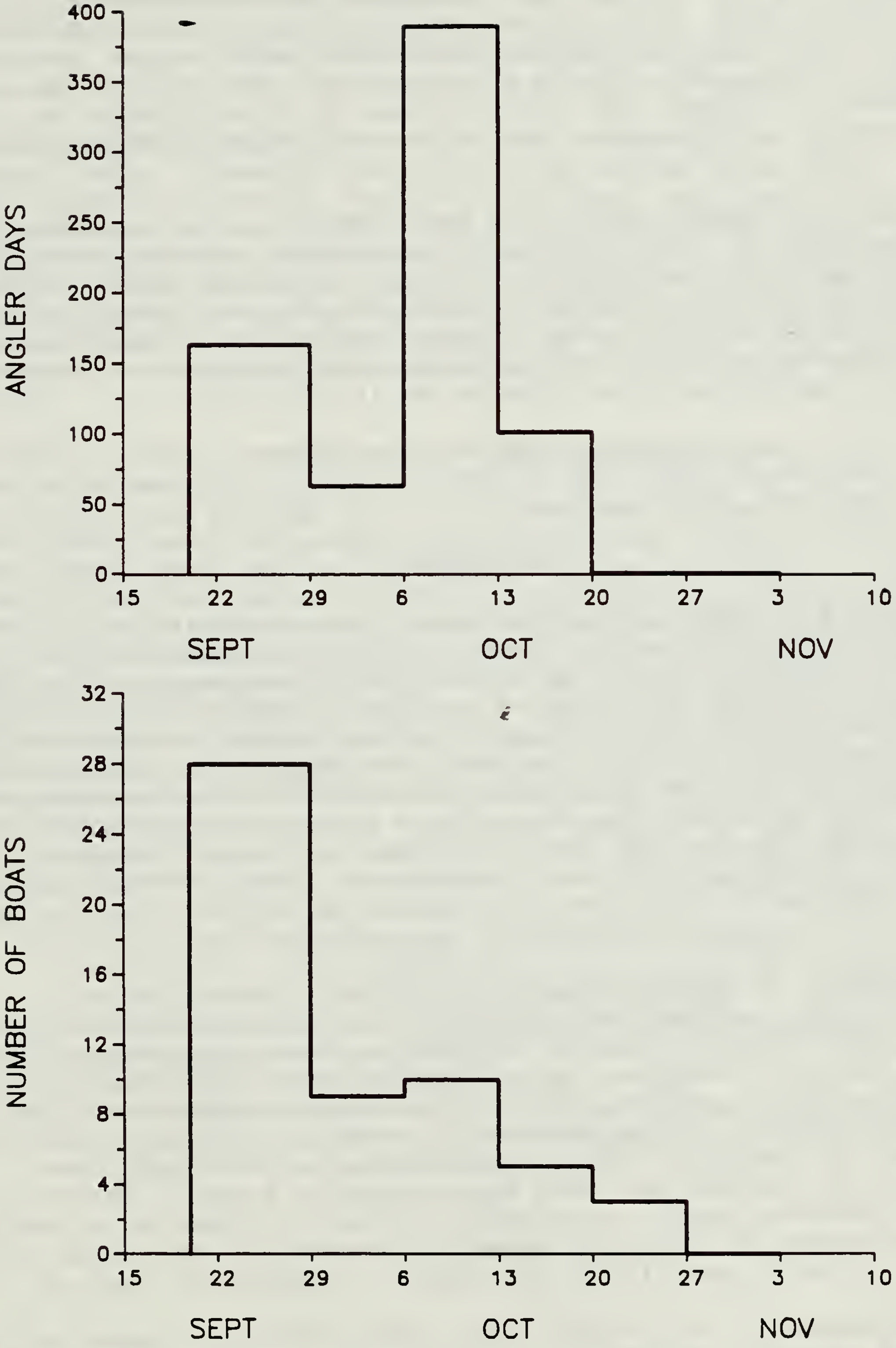

FIGURE 52.-Estimates of angler use and boat use in the Lewis River Channel, 1991.

the channel. In 1990 and 1991, trends in eagle counts closely followed those for brown trout spawners, and evidence of eagle predation on trout (e.g., blood spots accompanied by eagle wing prints in the snow) was common. The most bald eagles counted in a single day was seven on 31 October 1990; however, determining the number of eagles that use the channel within years is confounded by difficulties in seeing and identifying individuals birds.

Trumpeter swans arrived on the channel in late October or early November in 1990 and 1991; these birds may be attracted to the open water and beds of *Elodea* sp. (McEneaney, pers. comm.). Counts of swans were highest in early-to-mid November, and some of these birds probably stay through the winter. Swans are most often observed north of Harvey's Point (upper part of Reach 2) until this area ices over in mid- to late November.

No bear sign was found during the first 2 years of the study, indicating that the channel is not a high bear-use area during fall and early winter.

Discussion

Results indicate that the brown trout spawning run in the Lewis River Channel begins, peaks, and ends earlier than previously reported by Jones et al. (1977); consequently, almost the entire run can be fished by anglers. Angler use and effort are expected to be higher in years when October weather is mild than in years when October is cold and snowy, although interviews with anglers revealed that there are individuals who seek the "best" fishing regardless of weather. It is also apparent that this fishery has evolved from one that was largely harvest-oriented in the early 1970s (Jones et al. 1977) to one that is essentially catch-and-release, despite the current regulation that allows creeling two fish of any size per day.

Although it appears that brown trout are not being overharvested, anglers wading in the channel while fishing may disrupt brown trout spawning activity. Also, walking on redds while fishing or dragging boats through spawning areas may increase mortality of incubating brown trout eggs above that which would occur in the absence of human activity. Increased mortality of cutthroat trout *Oncorhynchus clarki* eggs from trampling by anglers has been documented in a small stream in Montana (Roberts 1988). Currently, however, there is no evidence to suggest that brown trout spawning success in the Lewis River Channel is being negatively affected by angling or boating.

Stalmaster (1987) noted that "high levels" of human activity disrupted behavior patterns of bald eagles and displaced the eagles into marginal habitat. Observers in this study noted short-term disturbances of eagles (i.e., the birds would take flight) by boaters and hikers; however, cumulative effects over the brown trout spawning season are unknown. In 1990 and 1991, bald eagle counts in the channel area tended to be highest when counts of brown trout spawners were high and angler effort was declining, but actual relationships among eagles, fish, and human activity could not be determined with the current study design.

Trumpeter swans are particularly sensitive to human activity (Banko 1960). Observers in this study noted short-term disturbance of swans by boaters or hikers, but these field observations were not sufficient to suggest substantial cumulative effects. Boaters probably have the highest potential for disturbing or displacing swans, because boaters paddle directly by or through groups of swans. Thus far, disturbance of swans by boaters has been minimized by the fact that most swans arrived on the channel when boating was almost over for the season.

Conclusions and Recommendations

Hiking and angling in the Lewis River Channel during the brown trout spawning season apparently have little effect on brown trout, bald eagles, trumpeter swans, and bears; however, effects from boating on wildlife resources are poorly understood. Examination of backcountry permits revealed that most overnight boat trips to Shoshone Lake occurred in late September; boaters at this time are more likely to be interested in camping at the lake than in fishing the channel. Also, the number of overnight boat trips to Shoshone Lake decreased as the number of brown trout spawners increased; in 1990 and 1991, only about one boat per day travelled to Shoshone Lake during the week of peak spawning. Observers noted that most boaters on day trips beached their boats at the upper end of Reach 2 and walked upstream to fish. Based on current results, it is recommended that:

1) the channel remain open to visitor use until park roads close rather than be closed on 15 October as proposed in the original study plan;
2) data collection continue on brown trout spawning, eagles, swans, and bears;
3) the creel survey continue; and
4) boating be more thoroughly investigated to determine patterns of use and possible negative effects on wildlife resources.

NONANGLING USE OF THE AQUATIC RESOURCE

The Fishing Bridge and LeHardy Rapids areas of the Yellowstone River are closed to angling in order to protect native Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*. At these locations, visitors may observe trout and other wildlife associated with riverine habitats. Since 1978, the U.S. Fish and Wildlife Service has annually estimated the number of visitors and the amount of time visitors spent at Fishing Bridge and LeHardy Rapids. The goal of this project is to evaluate the importance to the public of nonangling uses (e.g., photography and viewing) of aquatic resources.

Study Areas

Fishing Bridge spans the Yellowstone River at the outlet of Yellowstone Lake (Figure 16), and the 1.6-km river reach immediately downstream of the outlet has been closed to angling since 1973.

LeHardy Rapids, a series of small cascades about 6 km downstream from the Yellowstone Lake outlet (Figure 16), has been closed to angling since 1949. In 1984, a boardwalk was constructed to enhance visitor access and prevent serious erosion of the trail to the rapids. In 1985, a location sign was erected at the vehicle pullout. In 1991, the LeHardy Rapids area was closed to the public until 7 June to minimize disturbance of harlequin ducks *Histrionicus histrionicus*, an uncommon species in the park which uses the rapids area in May and early June.

Methods

A "time-available" methodology (Mathisen 1949; Bulkley 1966; Geiger 1972; Brown 1978) is used each year to estimate visitor numbers and visitor hours at Fishing Bridge and LeHardy Rapids. At each site, daily visitation patterns are determined from instantaneous counts of visitors made by U.S. Fish and Wildlife Service and National Park Service personnel between May and early October. Counts are usually made incidental to other activities, especially travel to and from work sites. On four or five randomly selected weekdays, mean length of visit is determined by recording the amount of time visitors spend at the site. Data for a particular site are pooled, and mean length of visit is calculated by dividing the total time spent at a site by the total number of visitors observed.

A daily visitor-use curve, partitioned into 15-min time intervals, is developed for each site. Total visitor hours for each 15-min time interval are then calculated by:

$$\text{Visitor hours} = 1/2\ I\ (t_i + t_{i+1}),$$

where I is the time interval, and t_i is the mean number of visitors counted in interval i. To obtain a daily total for visitor hours, instantaneous counts are expanded by the proportion of daily use represented by each time interval. On days when more than one count is made, the mean number of visitor hours is used. Total visitor numbers for each day are obtained by dividing visitor hours by the mean length of stay. Season totals are calculated by summing daily totals and then expanded by the proportion of days actually counted.

Results

Current Year

In 1991, about 302,000 people spent nearly 62,000 h at Fishing Bridge; the average visit lasted 12.3 min. The 1991 estimates for visitor numbers and visitor hours dropped 21% and 7% compared to 1990.

Nearly 220,000 visitors spent almost 35,000 h at LeHardy Rapids; the average visit lasted 9.5 min. The 1991 estimates for visitor numbers and visitor hours may be low because of the delayed opening; however, 1991 estimates are 72% and 80% higher than the 1990 estimates and are the highest yet reported for this area.

Long-term Trends (1978-1991)

From 1978 through 1987, visitation at Fishing Bridge was relatively stable (Figures 53 and 54). During this 10-year period, estimated visitor numbers never exceeded 210,000 per year, and visitor hours never rose above 36,000 per year. A substantial increase in visitation began in 1988, and this trend has continued through 1991 (Figures 53 and 54). Over the past 4 years, estimated visitor numbers have ranged from 256,000 to 383,000 per year, and visitor hours have fluctuated between 46,000 and 67,000 per year.

At LeHardy Rapids, visitation patterns were relatively stable from 1978 through 1984 (Figures 53 and 54). During this 7-year period, estimated visitor numbers never rose above 46,000 per year, and visitor hours never exceeded 4,100 per year. A sharp rise in visitation at LeHardy Rapids began in 1985 when the location sign was erected, and visitation has remained high since then (Figures 53 and 54). From 1985 through 1991, estimated visitor numbers have fluctuated between 106,000 and 220,000 per year, and visitor hours have ranged from 16,000 to 35,000 per year.

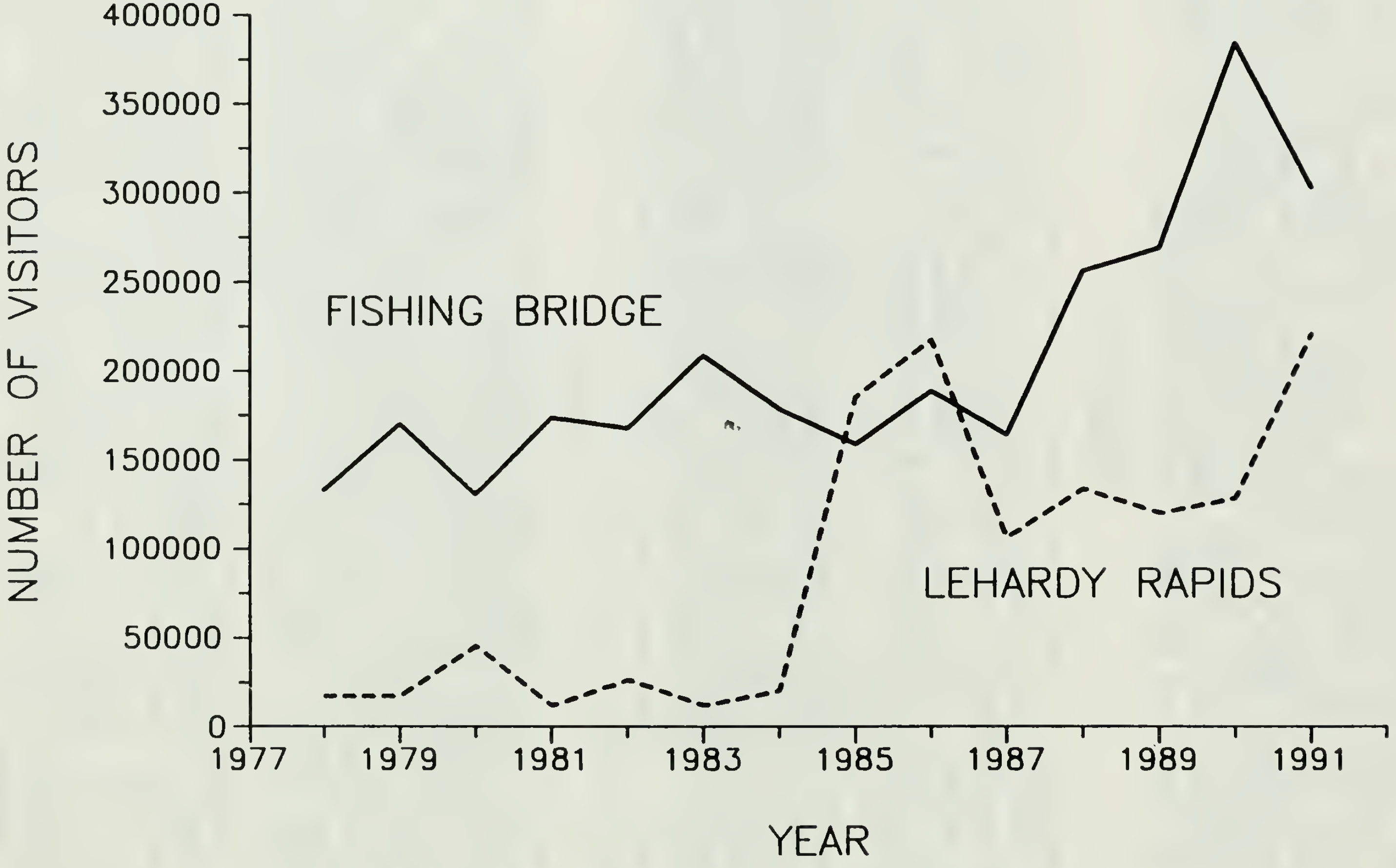

FIGURE 53.-Annual estimates of the number of visitors at Fishing Bridge and Lehardy Rapids, Yellowstone National Park, 1978-1991.

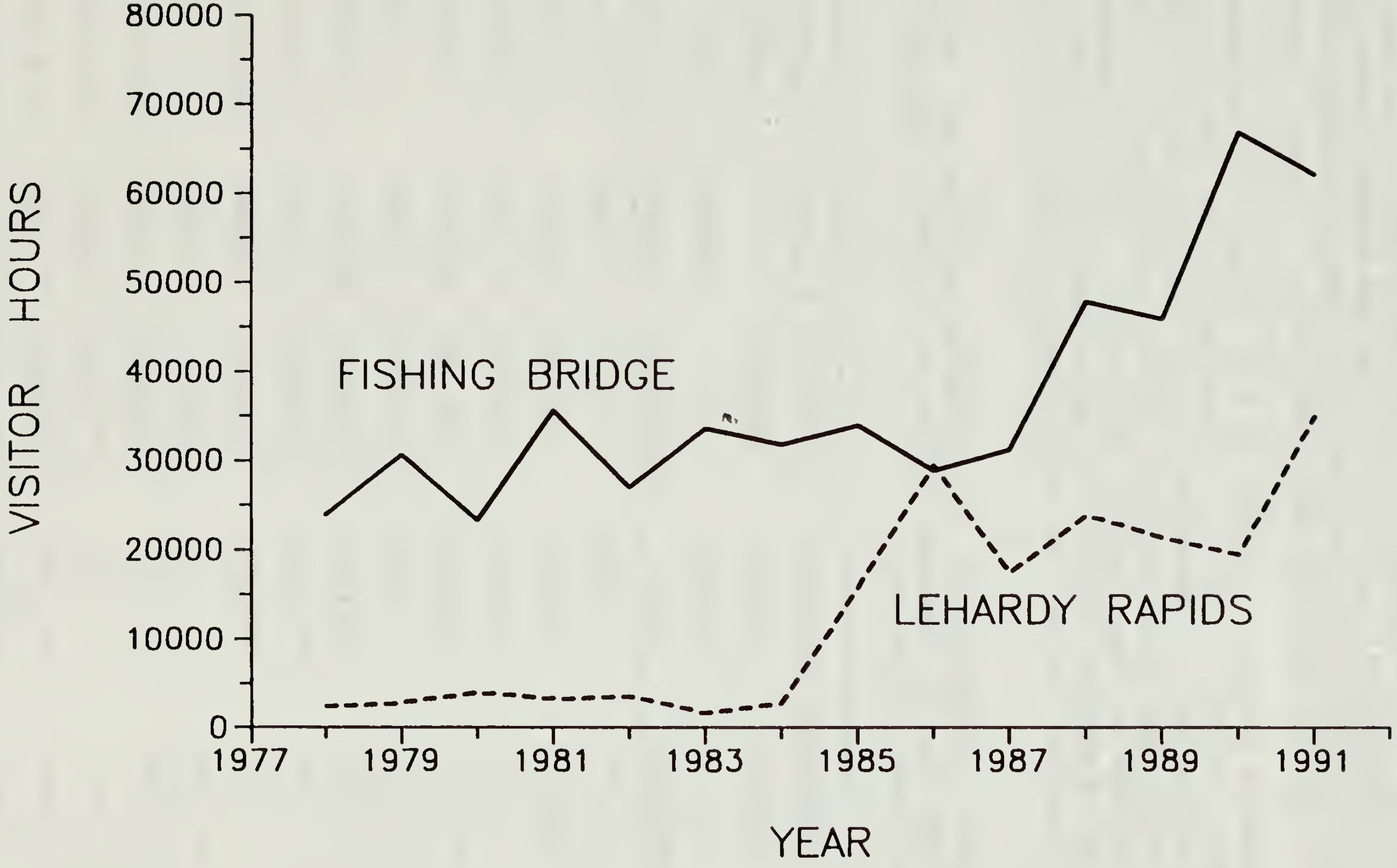

FIGURE 54.-Annual estimates of visitor hours at Fishing Bridge and LeHardy Rapids, Yellowstone National Park, 1978-1991.

Nonangling Use vs. Angling (1978-1991)

Comparisons of annual estimates of visitation at Fishing Bridge or LeHardy Rapids with annual estimates of angling in Yellowstone National Park reveal that for 12 of the past 14 years more people have stopped at Fishing Bridge than have fished in the park (Table 40). In 1991, the estimated number of visitors at LeHardy Rapids was greater than the estimated number of park anglers for the third time (Table 40).

Because average length of the angler day is much greater than mean length of visit at Fishing Bridge or LeHardy Rapids, annual estimates of parkwide angler effort (total hours fished) have always been greater than annual estimates of visitor hours at the bridge or the rapids (Table 40). Nevertheless, Fishing Bridge and LeHardy Rapids are among the top 10 when compared, in terms of hours, to angler effort among individual park fisheries.

Table 40.-Estimates of parkwide angling vs. estimates of nonangling use at Fishing Bridge and LeHardy Rapids, Yellowstone National Park, 1978-1991.

	Parkwide angling		Fishing Bridge		LeHardy Rapids	
Year	Number of anglers	Angler effort (hrs)	Number of visitors	Visitor hours	Number of visitors	Visitor hours
1978	155,700	744,400	133,000	23,900	17,300	2,400
1979	139,100	725,300	170,400	30,700	17,600	2,800
1980	130,800	758,000	130,300	23,200	45,600	4,000
1981	160,000	923,000	173,700	35,600	12,100	3,300
1982	152,000	777,600	167,300	26,900	26,800	3,600
1983	120,500	652,100	208,700	33,600	12,200	1,600
1984	135,000	790,100	178,000	31,700	20,700	2,800
1985	123,800	688,500	158,400	33,900	185,500	15,800
1986	124,900	734,700	188,700	28,800	217,400	29,500
1987	151,500	917,800	163,600	31,200	105,900	17,400
1988	134,600	753,400	255,900	47,800	133,500	23,800
1989	124,400	801,300	268,600	45,700	119,800	21,300
1990	150,400	1,042,900	383,500	66,700	128,500	19,400
1991	161,100	1,072,200	302,000	61,900	220,400	34,900

Discussion

It is apparent from the visitation levels at Fishing Bridge and LeHardy Rapids during the past 14 years that watching fish and other riverine-associated wildlife is important to the public. If visitation to Yellowstone National Park continues to rise, it is probable that the demand for such nonangling opportunities will increase. After all, observing wild animals in their natural habitat is not only fun but can be an educational experience for park visitors.

OTHER PROJECT ACTIVITIES

Management Activities

Reese Creek.-The National Park Service reached an agreement with the Church Universal and Triumphant (owner of the Royal Teton Ranch) regarding water rights and the diversion of water from Reese Creek, the only Yellowstone National Park stream that is diverted for irrigation use outside the park. A tributary of the Yellowstone River, Reese Creek is often entirely dewatered downstream from the diversion structures. Reese Creek has a resident population of Yellowstone cutthroat trout X rainbow trout intergrades (on the basis of electrophoretic analyses performed in 1991 on 22 specimens from the creek reach just upstream from the diversions). In addition, Yellowstone cutthroat trout from the Yellowstone River spawn in lower Reese Creek, downstream from the diversions, in years when flows significantly exceed diversion requirements.

Project personnel helped design new flow-control structures for the three irrigation diversions on Reese Creek. Construction and installation of these structures was completed in December 1991. Structure design allows upstream movement of fish over the diversion and screens prevent fish from entering the diversion ditches. Project personnel will continue to be involved with development of operational plans for these structures. Further negotiations with the Church Universal and Triumphant could lead to enhanced flows in lower Reese Creek and improved spawning habitat for Yellowstone cutthroat trout.

Gallatin River.-In early 1991 Montana Department of Fish, Wildlife and Parks personnel (Bozeman office) requested that our project participate in an assessment of the rainbow trout and brown trout populations of the Gallatin River near the Yellowstone National Park boundary. Fish, Wildlife and Parks was responding to sportman concerns that angling in the Gallatin River reach managed by Montana was leading to the depletion of trout stocks. Two Gallatin River study reaches were selected for a comparative investigation conducted in September 1991: Black Butte, in Yellowstone National Park, and Snowflake Springs, an adjacent reach just outside the park.

Results of the electrofishing surveys showed remarkable similarity between reaches, an estimated 358 trout (8 to 18.9 inches long) per mile in the Black Butte reach and 350 in the Snowflake Springs reach. A major difference between study areas was evident, however. An estimated 19 large (16 to 18.9 inches long) rainbow trout per mile occurred in the Black Butte reach, whereas none were found in the Snowflake Springs reach.

Yellowstone River drainage sediment study.-For the past several years our project has had a lead role in a study of the sediment dynamics of the Yellowstone River drainage. Focusing on Soda Butte Creek, the Lamar River, and the Yellowstone River downstream, the study was implemented in response to the belief held by a local anglers organization and the Montana Department of Fish, Wildlife and Parks that the frequency of highly turbid conditions in these rivers has increased dramatically during the past 2 decades. These persons speculated that high turbidity results from overgrazing of riparian and upland areas by elk and bison and an attendant increase in the rate of streambank erosion in the Lamar drainage.

This study involves sediment sampling on streams of the Yellowstone River drainage in the park and along the Yellowstone River in Montana. Project personnel spent approximately 15 man-days coordinating the study in 1991. Field work is performed by the National Park Service hydrology staff. The study is funded by the National Park Service, several other federal and state agencies, and Trout Unlimited of Livingston, Montana. A report on study progress is presented elsewhere in this document.

Soda Butte Creek.-Soda Butte Creek is a tributary of the Lamar River in the northeast corner of Yellowstone National Park. The upper reach of Soda Butte Creek, between Cooke City, Montana, and the park boundary, receives heavy metals (particularly iron) leached from the tailings of a long-abandoned gold mine. The tailings are a U.S. Environmental Protection Agency (EPA) Superfund site and cleanup of the area is planned. Since 1984, our project has collected macroinvertebrate samples from 5 or 6 locations on Soda Butte Creek. Samples are collected quarterly and analyzed by Fred Mangum, U.S. Forest Service. Dr. Mangum has prepared two reports discussing effects of the mine tailings on the aquatic macroinvertebrates of Soda Butte Creek. Analyses of macroinvertebrates are funded by EPA.

Global climate change investigation.-In 1991 the project began a long-term investigation of the possible effects of global warming on the trout populations of the lower Firehole River. The Firehole River receives substantial amounts of geothermally heated water from three geyser basins in the drainage. Although these heated, mineralized waters greatly increase the productivity of the Firehole River and contribute importantly to the fishery, they also elevate summer water temperatures to levels that can be harmful or even lethal to trout. To escape these elevated temperatures, trout move into coolwater refuges in tributary streams and mainstem areas upstream from the sources of geothermal effluents.

The availability of coolwater refuges could limit the trout community of the Firehole River. Such effects on the trout community could increase with global warming, which we speculate would increase the frequency of especially warm summers and the duration of trout use of the coolwater refuges each year. In such a scenario, global warming could lead to extirpation of the trout populations in geothermally heated reaches of the Firehole River.

The objectives of this study are to monitor the frequency and duration of use of coolwater refuges by trout from the Firehole River during summer, and to determine the relations between this use and water temperatures in the geothermally heated areas of the river. In addition, possible relations between coolwater-refuge use and the long-term trends in the fish community and fishery of the Firehole River will be investigated.

Assistance to Visiting Researchers

The largest intact ecosystem in the earth's temperate zone, Yellowstone National Park comprises 890,000 hectares of nearly pristine wilderness. The park, designated a biosphere reserve in 1976, contains some of the most diverse geothermal, geological, and biological resources in the world. Scientists are recognizing the importance of natural ecosystems and are coming in increasing numbers to conduct studies in Yellowstone National Park.

The Yellowstone Fishery Assistance Office functions as an administrative liaison and provides logistical support to visiting researchers working on aquatic studies in the park. Project personnel work closely with researchers to facilitate economical and timely completion of research. Project equipment, manpower, and facilities are provided without compensation for small studies and on a reimbursable basis for larger studies.

In 1991, the project provided laboratory space and boats to Drs. Edward Theriot and Sherilyn Fritz (National Academy of Sciences, Philadelphia, and University of Minnesota, respectively). Their research involves the evolution of diatom species in Yellowstone Lake and other lakes of the Yellowstone region. In addition to sampling living diatoms, they use sediment cores taken from the lake bottoms to determine the composition of the diatom communities during the past two- to three-thousand years. Sediment is deposited on the bottom of Yellowstone Lake at the rate of about one millimeter per year; about 70 percent of this sediment consists of the silicone-based shells of diatoms.

The project provided housing, office space, equipment, and 10 days of assistance to Dr. Cathy Whitlock and Ms. Sarah Millspaugh, both with the University of Oregon (Eugene). They are studying the frequency of wildfires during the post-glacial period and its relation to long-term vegetational and climatic changes in Yellowstone National Park. Sediment core samples taken from lakes in the park provide the materials used in their studies.

The project provided horses and 20 man-days of assistance to Wayne Minshall, Idaho State University, and his graduate students. Dr. Minshall is studying the effects of the 1988 wildlifes on stream ecosystems in the park.

Project personnel assisted Steve Hostetler, U.S. Geological Survey, Boulder, Colorado, with the collection of data needed to develop a temperature model for Yellowstone Lake. A continuous-monitoring weather station was set up near Pelican Point on the northeast shore of the lake and data collected there were downloaded about semi-monthly and sent to Dr. Hostetler. Among the benefits of the forthcoming temperature model for Yellowstone Lake is the possibility that it will help us better understand the causes of variation among years in the growth rates and year-class strength of Yellowstone cutthroat trout.

Office space and vehicles were provided to the National Park Service Research Division in support of various studies in the park.

Other Cooperative Activities

Bear Creek enters the Yellowstone River at Gardiner, Montana. The Mineral Hill gold mine at Jardine, Montana, is on Bear Creek. Discharge of water from mine operations could affect the water quality of Bear Creek. Although Bear Creek is outside Yellowstone National Park, the project has participated in a cooperative water quality monitoring study of the creek. Macroinvertebrate sampling equipment and 10 man-days of assistance were provided in 1991. Other cooperators are the U.S. Forest Service, Montana Department of Fish, Wildlife and Parks, and the Bear Creek Council, a citizens group.

The project provided technical assistance to the Beartooth Alliance, a citizens group headquartered in Cooke City, Montana. The Beartooth Alliance plans to monitor the macroinvertebrates and water quality of streams in three drainages near Cooke City. These streams may be affected by the proposed New World Mine, a gold mine whose operation could also affect Yellowstone National Park resources.

Volunteer Program

The volunteer programs of the U.S. Fish and Wildlife Service, National Park Service, and Student Conservation Association (SCA) have been important to the success of Yellowstone Fishery Assistance Office activities for many years. In addition to being important sources of manpower for our project, these volunteer programs provide valuable on-the-job training for volunteers. In 1991, volunteers provided 317 man-days of assistance to the project (274 man-days of which were by SCA personnel). Volunteers were involved in all phases of project work.

Information Distribution

Information collected by the Yellowstone Fishery Assistance Office is made available to the scientific community and the general public in several ways. The most evident of these modes of communication is our annual reports. However, the project receives numerous requests each year for information not found in annual reports. Responding to these special requests may require as little as 10 minutes of effort to as much as several man-days when extensive searching of data files and other records is necessary.

Reports

Fishery and aquatic management program in Yellowstone National Park: Technical Report for Calender Year 1990. 164 pp (Annual report for the project.)

Preliminary plan for restoration of fluvial Arctic grayling in Yellowstone National Park. 22 pp. (In Yellowstone National Park, fluvial Arctic grayling occurred historically in the Madison River drainage. However, because of probable negative interactions with introduced, non-native salmonids, the fluvial grayling may no longer occur in the park. This document presents a preliminary plan for the restoration of fluvial Arctic grayling to Yellowstone National Park.)

Seasonal use of coolwater refuges by trout in the Firehole River, Yellowstone National Park. 21 pp. (Annual report for the global climate change investigation on the Firehole River.)

Oral Presentations

Gardiner Fly Fishers, Gardiner, Montana; Federation of Fly Fishers National Conclave, West Yellowstone, Montana; West Yellowstone Chapter of Trout Unlimited; Upper Snake River Chapter of Trout Unlimited, Idaho Falls; Bozeman, Montana, Chapter of Trout Unlimited; Jackson, Wyoming, Chapter of Trout Unlimited; Visiting field zoology class from The Colorado College, Colorado Springs, Colorado; Visiting fire ecology class from the Teton Science School, Kelly, Wyoming; Visiting Fisheries Management class, Montana State University, Bozeman; Student Wildlife Forum, Montana State University; National Fisheries Research Center - Great Lakes (USFWS), Ann Arbor, Michigan; Public Education Program of the Yellowstone Institute, Yellowstone National Park; National Park Service resource management and naturalist training sessions, outfitters meeting, and concessioners meeting, Yellowstone National Park; U.S. Fish and Wildlife Service Project Leader's meeting, Bozeman.

The Project Leader lectured on fisheries management in the national parks at the U.S. Fish and Wildlife Service Fisheries Academy, Leetown, West Virginia.

Numerous newspaper, radio, television, and personal interviews were granted to the press in 1991.

ACKNOWLEDGMENTS

We thank the people who helped accomplish the many activities of the Yellowstone Fishery Assistance Office during the past year.

Janet Robertson, Office Assistant, joined the staff in August, after Karrie West accepted a position with the National Park Service (NPS). Janet left the project in November when she and her husband relocated to Cheyenne, Wyoming. In addition to her administrative duties, Janet had primary responsibility for the computerization of data. Mary Beth Martinec ably assumed these responsibilities in late November.

Glenn Boltz (Biological Technician) supervised field crews at Clear Creek and on stream surveys in summer, analyzed fish scales and maintained fish age-growth files. Glenn also provided important field assistance to independent researchers throughout the year.

During the 1991 field season, Scott Relyea and Mike Kiehn (USFWS and NPS Biological Aides, respectively), and Sean Hayes, Joe Hlivia, and Vince Hendricks (all with the Student Conservation Association), were the core of our summer field crew. Sean remained with the project into December and conducted the field work for the study on the Lewis Channel in fall. Dave LaConte (NPS Volunteer in Parks) assembled data on the Firehole River during winter 1990-91. Ken Barbalace (NPS Volunteer in Parks) participated in the work at Clear Creek before moving on to his summer job with TW Recreational Services in Yellowstone. Other project volunteers were Bob Murphy, Jim Williams, Adele and Jim Hayes, Gayle Smith, Denise Buonato and Mark Douma. Bill Hankinson (high school science teacher from Connecticut) spent 2 weeks assisting all aspects of our summer field program. Janet Lewis (National Park Service) assisted the fall gillnetting effort, as did Crystal Hudson (Ft. Morgan Fish Health Center, USFWS) and Bob Koby (Bozeman Fish Technology Center, USFWS). Wendy Husk helped prepare computer graphics for this report.

National Park Service District Rangers Joe Evans, John Lounsbury, and Jerry Mernin and their staffs provided logistical support for project activities. National Park Service Resource Management Coordinators Roger Andrascik, Craig McClure, Tom Olliff, and Jim Sweaney provided logistical support, ensured that the exit-gate surveys of anglers were completed on schedule, and participated in field activities.

George McKay (National Park Service) assisted with application of the Geographic Information Service to fisheries data. Dr. George Roemhild (professor emeritus, Montana State University) and Dr. Fred Mangum (U.S. Forest Service) analyzed aquatic macroinvertebrate samples collected in 1991. Dr. Roemhild graciously volunteered to build a collection of macroinvertebrates from park waters for curation in the Yellowstone Museum and began this important project in 1991.

Bob Gresswell (Fishery Biologist, USFWS), Ph.D. student at Oregon State University, returned to Yellowstone during the summer. Bob provided valuable assistance to the project, particularly in the area of computer programming.

This report was submitted by:

Ronald D Jones

Ronald D. Jones, Project Leader

Reviewed by:

Larry Visscher

Larry Visscher, Associate Manager - Fisheries
Fisheries and Federal Aid, Region 6, USFWS

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